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Natural Gas Engine-Driven Heat Pump Demonstration at DoD Installations

Performance and Reliability Summary

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Final Report

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Abstract: Results of field testing natural gas engine-driven heat pumps (GHP) at six southwestern U.S. Department of Defense (DoD) installations show that the technology can provide both energy savings and resource conservation. A summary is provided of three main objectives: (1) verifying technical feasibility of GHP technology for space heating and cooling applications, (2) field operation experience from the beta version of GHP systems for final product development, and (3) analyzing energy and economic performance of GHP systems during a 1-year period. During testing from April 2007 to March 2008, the units produced an average unit coefficient of performance (COP) of 1.38 in the heating season and 1.25 in the cooling season. These efficiencies translate to annual energy cost savings in heating and cooling at each site that ranged from $680–$2,134, as compared to using high-efficiency electric heat pumps (EHP). In addition, an estimated 261,473 gallons of fresh water was saved at power plants, due to the reduced consumption of electricity. Lessons learned from this project are implemented in further development of GHP technology. Field demonstration of the follow-up model is in progress at five DoD installations for FY08,to be the topic of a future technical report.

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Preface

This study was conducted under the Project known as , "GEDAC Demo at DoD Installation." Language for this project was identified in 2006 Department of Defense (DoD) Appropriations Bill of the 109th Congress (1st session) Report 109-359, p. 363, "Making Appropriations for the Department of Defense for the Fiscal Year Ending September 30, 2006, and For Other Purposes." Funding was made available under "Program Element (PE) 0603734 FY06 GEDAC Package Gas Engine Driven Heat Pump (multi state)". The technical monitors were Robert Boyd, ODDRE&E, and Dudley Sondeno, Southwest Gas Corporation.

The work was managed and executed by the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL principal investigator was Chang W. Sohn. Dr. Tom Hartranft is Chief, CEERD-CF-E, and Michael Golish is Chief, CEERD-CF. The associated Technical Director was Martin Savoie, CEERD-g68-T. The Deputy Director of ERDC-CERL is Dr. Kirankumar V. Topurdurti and Director is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. James R. Houston.

Acknowledgements

Appreciation is given to the Energy Offices of the six participating DoD demonstration installations: Barstow Marine Corps Landing Base, California; Davis-Monthan Air Force Base, Arizona. Fort Huachuca Army Garrison, Arizona; Luke Air Force Base, Arizona; Nellis Air Force Base, Nevada; and Yuma Marine Corps Air Station, Arizona.

Unit Conversion Factors

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 yd	=	0.9144 m
1 sq in.	=	6.452 cm^2
1 sq ft	=	0.093 m^2
1 sq yd	=	0.836 m^2
1 cu in.	=	16.39 cm^3
1 cu ft	=	0.028 m^3
1 cu yd	=	0.764 m^3
1 gal	=	3.78 L
1 lb	=	0.453 kg
1 kip	=	453 kg
1 psi	=	6.89 kPa
°F	=	(°C x 1.8) + 32
Common marketing units for natural gas		
1 thm	=	10^5 Btu
1 Dthm	=	10^6 Btu
1 thm	=	(100/1.025) cf
1 Ccf	=	100 cf
1 cf	=	1.025 x 10^3 Btu
1 Mcf	=	1000 cf

1 Introduction

1.1 Background

Sustaining limited energy resources calls for increased energy efficiency in space heating and cooling applications. A gas engine-driven heat pump (GHP) system offers a more energy-efficient alternative to cooling and heating than using either a conventional electric air conditioner/gas furnace combination or an all-electric heat pump. In a GHP, the gas engine is used to generate power, then is employed to drive a compressor for the heat pump system. A GHP system is a distributed energy system that also offers an excellent energy-conservation opportunity by using waste heat for space heating application. In addition, distributed generation with a micro-grid system is an emerging trend for the alleviation of over-capacity electrical transmission lines and for utilization of alternative energy sources. Using natural gas for space-cooling applications can also help reduce electrical transmission capacity problems and provide energy conservation.

For a typical military installation, space cooling is the major factor in electrical energy consumption and peak electrical demand. For example, in a detailed study of electricity use at Fort Hood, TX, cooling was responsible for 54% of the total peak demand of electricity and 33% of the total electricity consumed (Akbari and Konopacki 1995). As a means of reducing the electrical energy requirement for space cooling, natural gas-powered cooling systems were introduced into the market in the 1990s. The economic benefit of electric/natural gas hybrid cooling systems was widely promoted in the air-conditioning industry during the 1990s. Natural gas cooling systems offered savings by reducing on-peak electrical demand and, at certain sites, by reducing the cost of energy from using natural gas instead of electricity. A review of the natural gas cooling systems and natural gas/electric hybrid cooling systems has been presented at an ASHRAE conference for industry professionals. (Sohn 2001).

In FY 2006, Congress funded demonstration of GHP units in DoD installations. The GHP demonstration unit was a heat pump unit that provided space cooling by a scroll compressor, driven by a natural gas-fired engine. It provided space heating by reversing the refrigeration cycle, with auxiliary heating augmented by the engine waste heat recovery. The project was administered by the U.S. Army Engineer Research and Development Center Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL, through a contract with the Blue Mountain Energy (BME), Las Vegas, NV. The goals of the demonstration project were: (1) field evaluation of the Natural Gas Engine Drive Air Conditioner (GEDAC) system's energy performance and cost savings through a 1-year heating/cooling operation cycle, (2) introduction of advanced heating and cooling technologies to military installations, and (3) documentation of field operations and maintenance (O&M) lessons for technology transfer to the Department of Defense (DoD) and the commercial market.

Most air-conditioners and heat pumps in the U.S currently are powered by electricity. An alternate source of power is desirable in order to reduce the summertime peak demand experienced by electric utilities and to provide energy cost savings to consumers. Heat pump systems powered by a small natural gas-fired engine have been successfully commercialized in Japan (Takahashi 2006). Takahashi states that in Japan, "The installed capacity of absorption-type and heat pump-type gas air-conditioning systems was 11.1 million refrigerant ton (RT) in FY 2004, a 5% increase over the previous year, and amounted to a 22.3% share of the entire air-conditioning capacity nationwide excluding residential use." (ibid, 6) Absorption-type cooling and heating systems came into widespread use in large buildings, and gas engine heat pump-type systems are popular in medium and small buildings." Similar GHP systems are being introduced in the U.S. market to provide consumers with energy-efficient space heating and cooling, as well as utility cost savings.

In 2007, six 10-ton GHP units were installed at six military installations to gather field test performance data for a full year (from May 2007 to April 2008). The locations were all in the southwestern United States. Note that normally high outdoor temperatures experienced in the Southwest present a challenging operating condition for any air-cooled air-conditioning system. The objective of this field test was to evaluate the energy conservation and cost savings potential of GHPs. Operational experiences from a prototype operating in this challenging environment provided valuable lessons for technology development that would transfer to the DoD and the commercial market.

1.2 Objective

The objectives of this report are: (1) to document the field demonstration of six units of 10-ton GHP system in six military installations in the Southwest region of the United States, (2) to analyze field energy performance of GHP units in space heating and cooling applications, and (3) to provide field operational data for refinement of the GHP technology, making it ready for commercialization.

1.3 Approach

A Broad Agency Announcement (BAA) contract* was awarded to BME. Major tasks of the contract included: (1) project initiation, (2) demonstration planning, (3) execution of demonstration, (4) performance monitoring, and (5) closing of project. A monthly progress report during the contract period from 10 Aug 2006 to 30 Sep 2008 was part of the required contract deliverables.

BME completed installation of six GHP units by 30 April 2007. A 12-month performance monitoring began in May 2007 and ended in April 2008. The monthly progress reports during the 12-month monitoring period documented performance of each GHP units at each demonstration site. This technical report summarizes the performance of those six GHP units by summarizing the monthly progress reports.

1.4 Scope

The six GHP units tested in this project were in the beta-stage of product development, and were not commercial-ready systems. Field testing was needed for proof of technical feasibility of this GHP system. The performance data in this report are for the refinement of the GHP technology to be used in final product development and commercialization.

Commercial-ready product specifications and commercial field performance data are beyond the scope of this technical report. That information will become available and be reported at the conclusion of the second

* ERDC-CERL, Contract Number W9132T-06-C-0024, "Natural Gas Engine-Driven Air Conditioner (GEDAC) for Demonstration Test on Military Installations," 10 Aug 2006.

round of the field demonstration contract* which will be concluded in March 2010.

1.5 Mode of technology transfer

This report will be made accessible through the World Wide Web (WWW) at URL: http://www.cecer.army.mil. The findings from this report will provide technical direction for further development of GHP technology. A portion of this report, on cooling performance, has been published in the transactions of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (Sohn et al. 2008).

* ERDC-CERL, Contract Number W9132T-08-C-0030, "Gas Engine-Driven Air Conditioner (GEDAC) Demonstration Test on Military Installations," 2 July 2008.

2 Demonstration of Natural Gas Engine-Driven Heat Pump (GHP) System Technology

2.1 Description of GHP system technology

The demonstration GHP system resulted from six years of research and development by the Southwest Gas Corporation branch at Phoenix, Arizona (corporate headquarters in Las Vegas, Nevada) and BME. The technology included a variable-speed, natural gas engine which powered a dual-circuit heat pump, allowing the unit to effectively meet customers' various demands. During conditions with low ambient air-temperatures, the technology also ensured that customers were always supplied with heat, due to the defrosting capabilities of the dual-circuit and heat-recovery technologies.

The demonstration units were 10-ton heat pumps known as the Model 5 GHP. These GHPs used a natural gas engine to power two compressors responsible for providing the work input for a dual-circuit heat pump. The engine was a three-cylinder, liquid-cooled, three-speed, internal combustion engine with an range of 1,400–2,400 RPM. To maximize the use of available energy, the engine's coolant system could recover waste heat through a series of heat exchangers. Once the engine coolant leaves the exhaust heat exchanger and the engine is up to the optimal operating temperature, a mixing valve opens, sending the recovered heat to the indoor coil in heating mode or to the outdoor radiator in cooling mode. This flow of engine coolant was provided from an electric centrifugal pump.

In addition to using an internal combustion engine, the Model 5 GHPs also had a distinctive dual-circuit design with a variable refrigerant volume (VRV) technology provided by the engine's variable speeds. Like traditional vapor-compression systems, the refrigerant left the compressors as a superheated compressed gas.

In cooling mode, the gas was sent to the outdoor coil, where the ambient air was pulled over a finned heat exchanger, condensing the refrigerant. This liquid was directed to the indoor section, throttled through a thermostatic expansion valve, and later evaporated by extracting heat from indoor air through a fin and tube heat exchanger. This evaporated refrigerant was then passed to the compressor, repeating the cycle.

When operating in heating mode, a reversing valve was actuated which diverted the refrigerant to enter the indoor coil first, adding heat to the environment by condensing the refrigerant. The condensed liquid bypassed the cooling-mode expansion valves, and was throttled through a secondary set of expansion valves. The low-pressure, part-phase refrigerant was then evaporated, using an energy input from the outdoor air. During conditions with low ambient temperature and high humidity, ice buildup can appear on the outdoor coils, greatly reducing the effectiveness of providing space heating. The GHP design combated this by reversing one of the refrigerant circuits, leaving one circuit in cooling and the other in heating, to supply a net-positive energy output to the indoor climate and to eliminate ice buildup. The system continued to operate in this fashion until the coil temperatures exceed freezing. If both coils are operating below freezing, they will individually alternate between heating and cooling until the coils are defrosted.

To gain a better understanding of the system's operation, the piping and instrumentation diagram can be seen in Figures 1, 2, and 3. Additionally, the physical design and layout of the unit is provided in Figures 4 and 5.

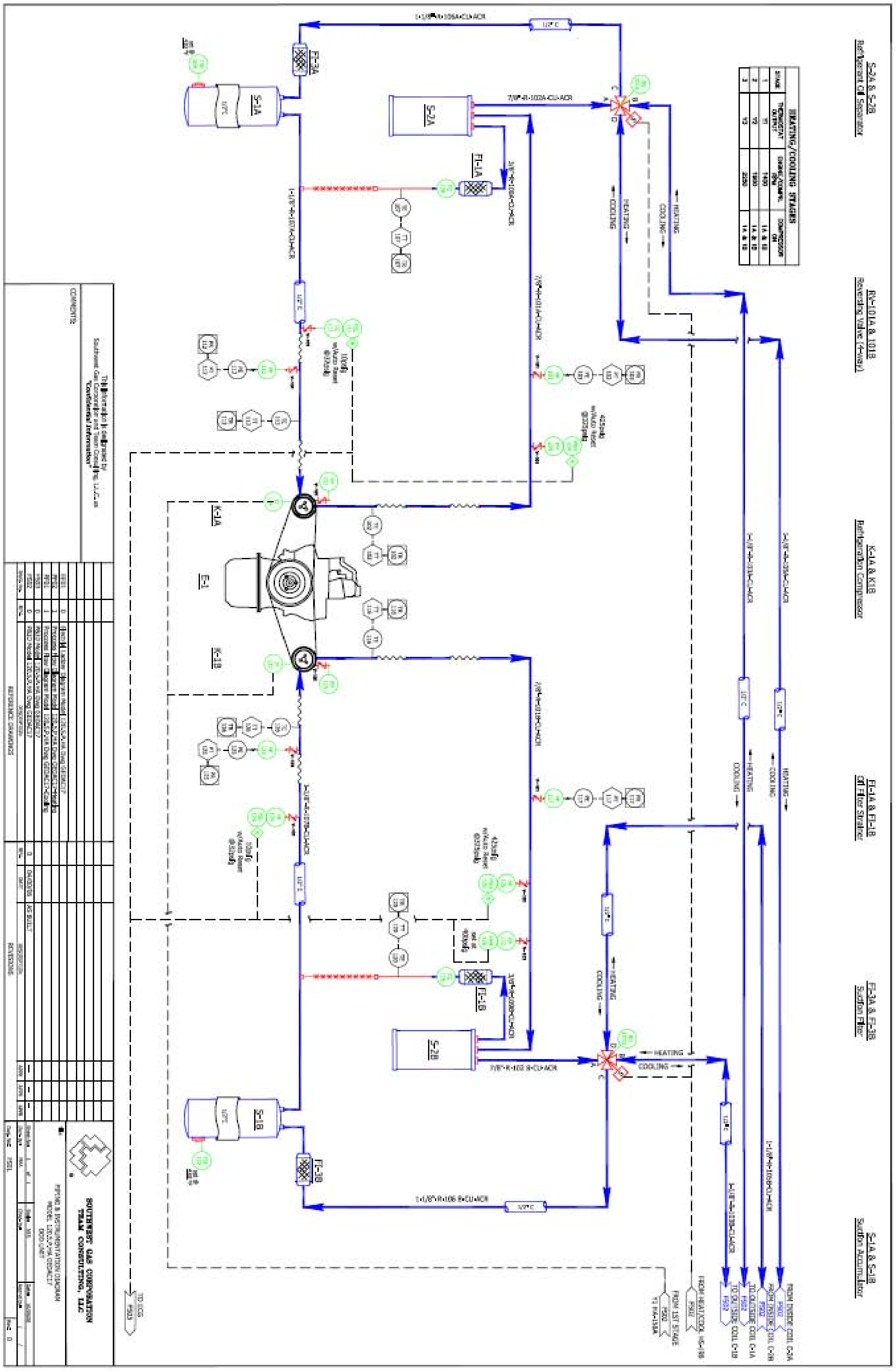

Figure 1. Model 120.5 piping and instrumentation diagram, displaying the arrangement of reversing valves, suction accumulators, oil separators, and dual-circuit compressors.

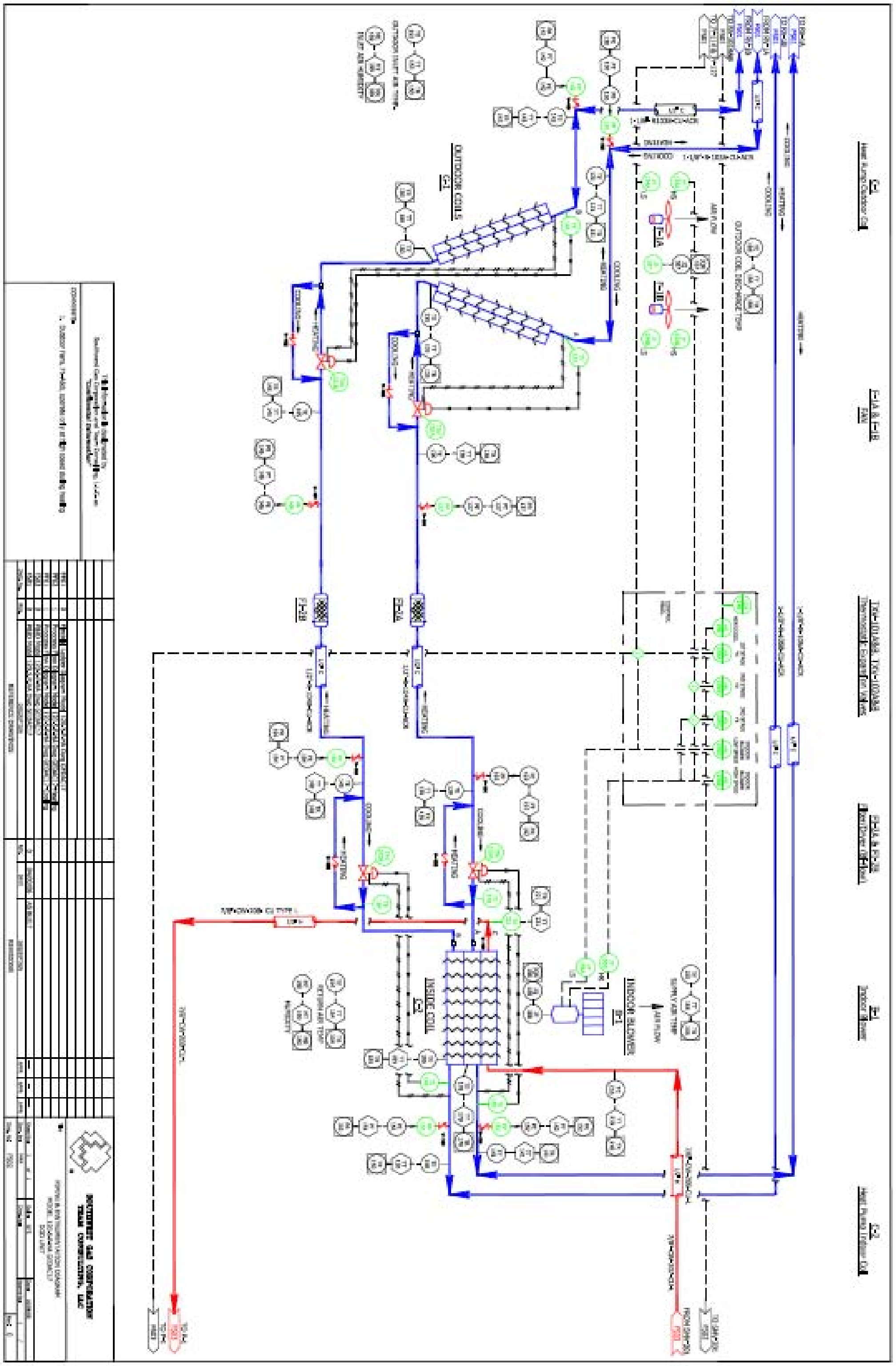

Figure 2. Model 120.5 piping and instrumentation diagram, displaying the configuration of the indoor and outdoor coils, along with the two different sets of heating and cooling mode expansion valves. The red line represents the heat recovery path for engine coolant in heating mode.

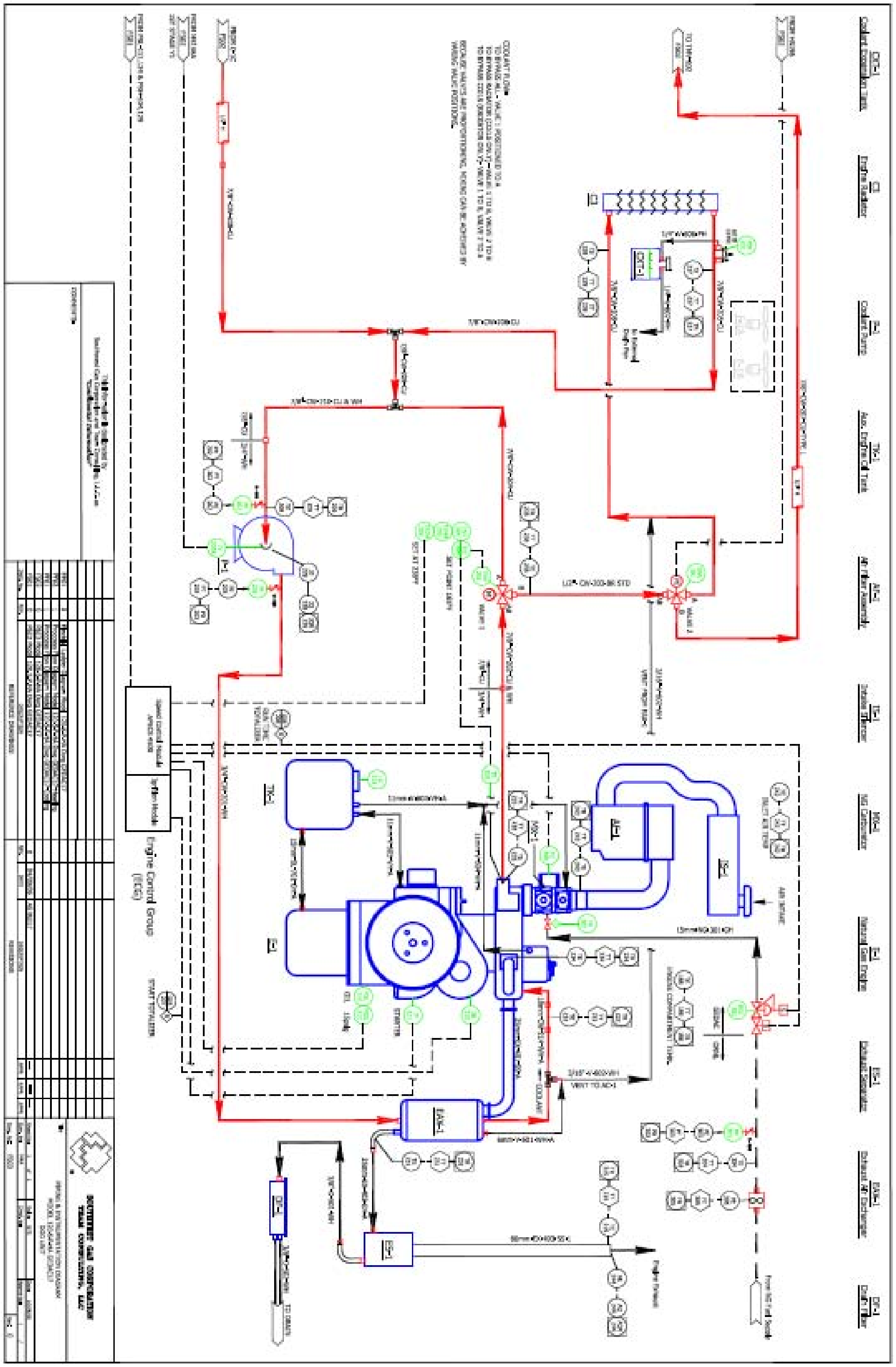

Figure 3. Model 120.5 piping and instrumentation diagram, displaying the details of the engine compartment, and the coolants path to the radiator and indoor coil.

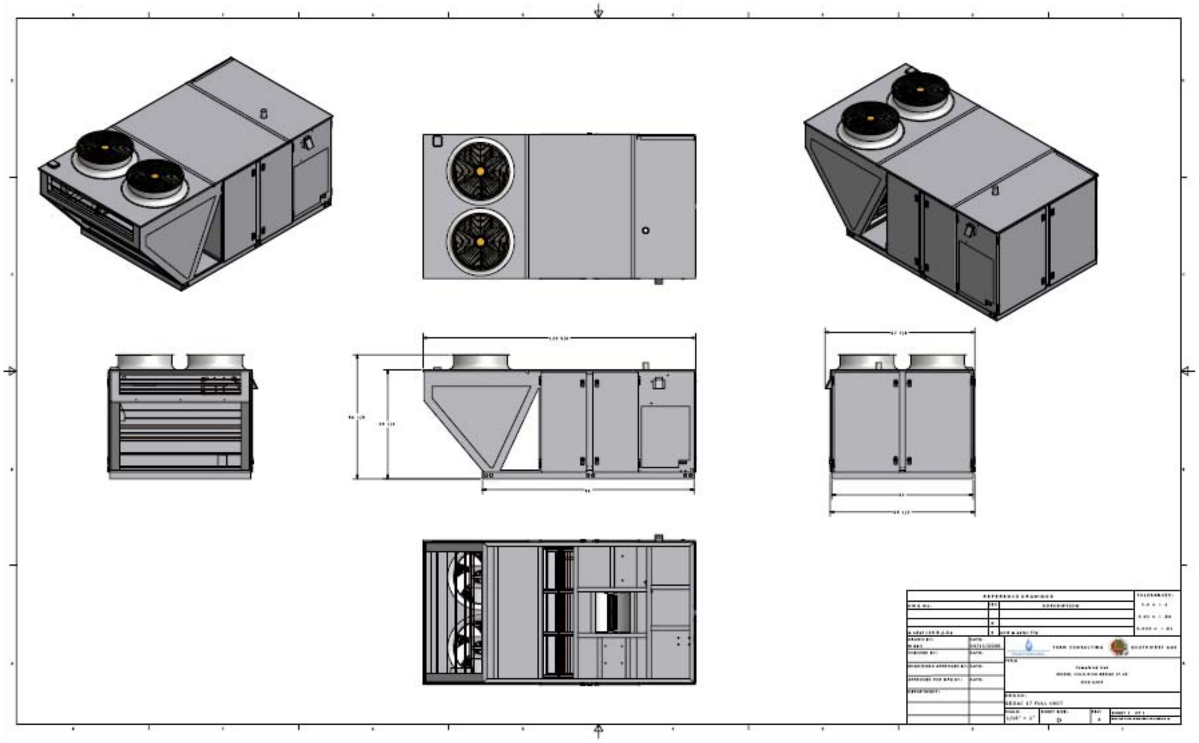

Figure 4. 3-D CAD drawings of the Model 5 demonstration gas heat pump.

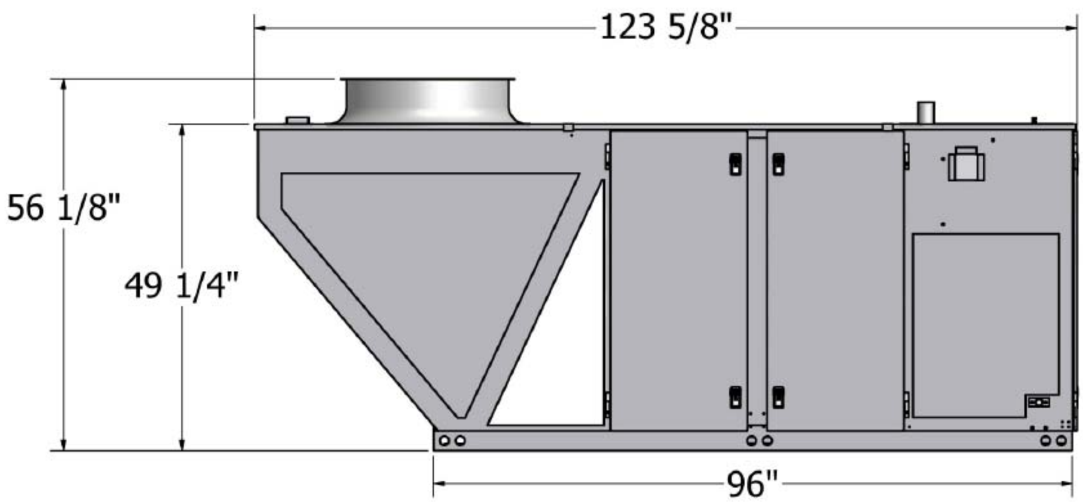

Figure 5. CAD drawing displaying the exterior dimensions of the Model 5 GHP.

2.2 Six demonstration sites and buildings

Six DoD sites were selected for this GHP demonstration, based on geographic serviceability and application diversity. It was important that the installations could provide a cross-section of high and low ambient temperatures and elevations to thoroughly test the capabilities of the GHPs. Davis-Monthan Air Force Base (AFB), Luke AFB, Nellis AFB, and Yuma Marine Corps Air Station (MCAS) are located in some of the hottest regions of the United States. Conversely, Fort Huachuca Army Garrison (AG) at 5,200 ft elevation and Barstow Marine Corps Logistics Base (MCLB) were selected for their particularly cold winter months. All six locations provided ample cooling and heating hours to supply sufficient testing data. Demonstration buildings with the six units of GHP system installed (numbered GHP #17-#22) are shown in Figures 6–11.

Figure 6. The 10-ton GHP Unit (GHP #17) installed at the fitness center on Marine Corps Logistics Base in Barstow, CA.

Figure 7. The 10-ton GHP Unit (GHP #18) installed at an office building at Luke AFB, AZ.

Figure 8. The 10-ton GHP Unit, left (GHP #19) shown side-by-side with a 7.5-ton Electrical DX Unit, right, installed at the dining hall at Nellis AFB, NV.

Figure 9. The 10-ton GHP Unit (GHP #20) installed at an office space at Davis-Monthan AFB, AZ.

Figure 10. The 10-ton GHP Unit (GHP #21) installed for an office space inside a warehouse at Marine Corps Air Station, Yuma, AZ.

Figure 11. The 10-ton GHP Unit (GHP # 22) installed at the museum at Fort Huachuca AG, AZ.

2.3 Instrumentation of demo systems

Since reliability, performance, and efficiency were all being examined, each of the six GHP units was equipped with data-logging devices. Each GHP unit had 14 pressure transducers, 32 thermocouples, 2 hygrometers, 1 watt transducer, and 4 flow meters; each connected to National Instrument's compact field modules that recorded data every 60 seconds. A discussion of each follows.

2.4 Thermocouples

The thermocouples obtained temperatures for the air-conditioner's airside and heat recovery capacities. Besides gaining information needed for capacities and efficiencies, thermocouples were also used to troubleshoot such unit failures as excessive engine temperatures and poor indoor-airflow conditions. The thermocouples were T-type, rated to 350˚F, with an error of ±2˚F.

2.5 Pressure transducers

In conjunction with the thermocouples, pressure transducers were used to obtain refrigeration capacities and to troubleshoot unit failures of extreme pressures. The pressure transducers also verified the correct refrigerant charges by allowing calculations for super-heats and sub-cools. These pressure transducers have a 4–20 mA output with a pressure range of 0–600 psig. The error is 1% of the full-scale output.

2.6 Flow meters

Flow meters were placed on the refrigerant liquid line, natural gas line, indoor coolant diverting line, and supply air ducts. They measured fuel, refrigerant, engine coolant, and air mass flow rates. The coolant, refrigerant, and natural gas meters on the units installed at Barstow, Luke, Nellis, and Davis Monthan had turbine flow meters with a 0–30mV output. The units at Yuma and Fort Huachuca had Coriolis flow and density measurement devices to measure coolant, refrigerant, and natural gas flow. It should also be noted that all the flow meters used in this project were extremely sensitive laboratory instruments whose accuracy is greatly affected by high turndown ratios. Knowing this sensitivity, a positive-displacement gas meter was used as a back-up on the gas supply line. The air flow meters for all the units are pitot averaging devices with a range of 0–5,000 cfm and output of 4–20 mA. With the robustness of the positive-displacement gas meter and indoor air flow meter, a sufficient backup was available if inaccuracies occurred in the flow measurements. These meters had various flow ranges with a maximum error of ±2% linearity.

2.7 Watt transducers

Watt transducers were used to acquire electrical power consumption data. This data was used to determine system efficiencies* , and modes of operation such as "lockout.†" The devices used have a full scale range of 0–10kW, an output of 0–5V, and an error of 0.5% full scale.

* System efficiencies account for the electrical, application-dependent, power consumption and natural gas input.

† Lockout is a failure mode of operation caused by a failure to start, high pressure/low pressure shutdowns, or high engine temperatures. Although the engine is no longer in operation, the indoor blower, condenser fans, and coolant pump still operate.

2.8 Hygrometers

Hygrometers were used to determine the relative humidity required for calculations of latent airside capacities. They operated from 0–95% relative humidity (RH) with a 4–20 mA output and a ±2% error at 77 ˚F.

2.9 Uncertainty analysis

When using the above instruments to gather different values for calculating the Coefficient of Performance (COP), a degree of uncertainty was introduced to the final value. For example, the COP is represented by the following variables: $COP(x_1, x_2, x_3, x_4, x_5)$. The uncertainty of the COP is then expressed by the following equation (Figliola and Beasley 2006):

$$W_{COP} = \left[\left(\frac{dCOP}{dx_1} \bullet w_1 \right)^2 + \left(\frac{dCOP}{dx_2} \bullet w_2 \right)^2 + \left(\frac{dCOP}{dx_3} \bullet w_3 \right)^2 + \left(\frac{dCOP}{dx_4} \bullet w_4 \right)^2 + \left(\frac{dCOP}{dx_5} \bullet w_5 \right)^2 \right]^{1/2} \quad [1]$$

where:

x = the value being measured (temperature, flow... etc.)
W = the corresponding uncertainty for each measurement.

Using Equation 1 with a random line of data, and assuming the confidence interval of the measurement devices to be within 95%, the COP has the overall uncertainty of ±.11 (95%).

2.10 Data compilation

Testing each unit with 60 measurement instruments, sampling 60 times an hour, 24 hours a day, 365 days a year, produced up to 3,153,600 pieces of data per unit. Because this data had to be summarized once a month, 275,400 bits of data were periodically averaged. To perform such a task, a Microsoft Excel macro was created that scans a data directory, opens each data file, copies it to an Excel file, and inserts the appropriate equations to determine capacities and COPs. Using the date value, the Excel program calculates the average values for each day and each month. The monthly data reports created by this macro are attached in the Appendixes B-G. A data record, representing all successfully transferred data from a demo site to the team's consulting analysis center is shown in Figure 12.

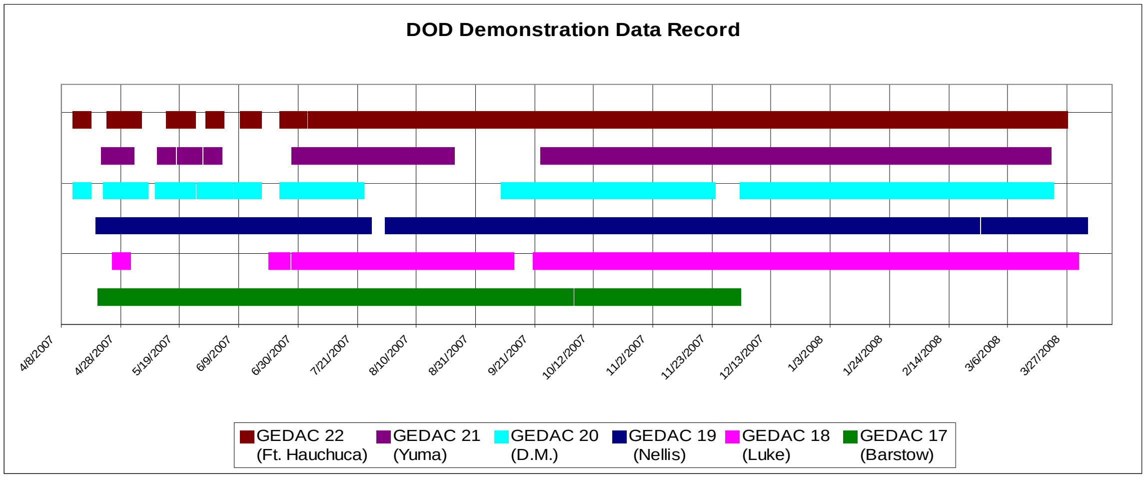

Figure 12. Data record representing times of available data with colored lines.

The inconsistent availability of data during the early months of testing (Figure 12) was due to the unreliable cellular transmission of data. Once the method of manual swapping flash memory cards was used (starting in August 2007), the availability of data drastically increased. However, the second half of testing data for the Barstow unit is unavailable because a weather breach short-circuited the backplane on the data modules.

3 Analysis of Performance Data

As seen in the preceding section, over 60 measurement devices were used to gather information on performance, economy, reliability, and energy efficiency. Because the flow meters proved to be inaccurate for instantaneous calculations, it was decided to greatly simplify the method of calculating the performance parameters by using the airside capacity and positive-displacement natural-gas flow meter readings.

3.1 Energy performance

3.1.1 Airside capacity

The airside capacity was determined by first converting the relative humidity of the return and supply ducts to dew point. Once the dew point was achieved, testers used a correlated relationship of enthalpy as a function of dew point at constant barometric pressure*. The mass flow rate was then gathered by utilizing the indoor air-flow meter, assuming a constant density from the average range of supply and return temperatures. The density of air only varied by 7 percent, from 60 °F–100 °F. Using the return and supply enthalpies from temperature and relative humidity, the capacity was gathered from the following equation:

$$Capacity_{Latent} = \dot{m}\left|h_{supply} - h_{return}\right| \quad [2]$$

where:

$\dot{m}$ is the mass flow rate of indoor air

h is the enthalpy of the return or supply

The absolute value was used to give positive capacities in both heating and cooling mode. The sensible energy was calculated using the following equation:

$$Capacity_{Sensible} = \dot{m}Cp\Delta T \quad [3]$$

where:

* Source: Oak Ridge National Laboratory

Cp = the specific heat of air

ΔT = the temperature difference between the supply and return air temperatures.

The latent capacity is then calculated by taking the difference between the sensible and total capacity.

3.1.2 Fuel consumption

Because the natural gas turbine flow meter for the fuel consumption could not handle the turndown ratio from the natural gas engine, the total cubic feet of natural gas was acquired from the onsite diaphragm gas meters. Using these gas readings, coupled with the GHP's hour counter, the average fuel consumption rate was supplied on a bi-weekly basis. For example, if the previous gas meter reading was 835 therms and the current is 843 therms, while the time elapsed between fuel readings is 16 hours, the fuel consumption is calculated as follows:

$$Energy\_Consumption_{Avergae} = \frac{843therm - 835therm}{16hour} * 100000 \frac{BTU}{therm} = 50{,}000 \frac{BTUs}{hour} \quad [4]$$

3.1.3 Coefficient of Performance

The Coefficient of Performance is defined as:

$$COP = \frac{Useful\ Conditioning\ Effect}{Costly\ Energy\ Input} \quad [5]$$

The "useful conditioning effect" is the energy extracted or supplied to the indoor air space, while the "costly energy input" is the natural gas and electrical power consumption. When consumption of electricity is taken into consideration in addition to the primary energy source (natural gas), the efficiency is called a system COP. If only the primary energy consumption is used, the efficiency is called a unit COP. When comparing the GHP technology to an EHP, the unit COP should be used because both technologies use the same secondary electrical components (outdoor fans and controls). Once a month, the intermittent average of the airside capacity and fuel usage was computed. These averages were compiled to acquire seasonal performance data.

3.1.4 Environmental

In the Southwestern region of the United States, one of the most precious resources is water. Over 39% of the nation's water consumption is due to thermoelectric power generation (Torcellini, Long, and Judkoff 2003). Use of GHPs greatly reduces the consumption of this resource. Multiplying the electrical usage difference by the total runtime gives the total kWh saved when using the gas engine-driven technology. These kWh are then multiplied by the nation's average power-generation water-consumption rate (estimated to be 2 gal. per kWh when considering thermal and hydroelectric power generation). Thus, this use of GHPs is calculated to save 261,473 gallons of water.

3.2 Economic performance

As mentioned previously, when bypassing secondary energy inefficiencies such as central power plant losses, significant economic gains occur. This report summarizes those savings, by recording the gas usage and hours of runtime and then, comparing them with the energy potentially consumed by an equivalent EHP. Calculating the expense of the costly energy consumed by the GHP can be expressed as follows:

$$GHP_{Operating\ Cost} = Therms_{Consumed} \cdot \frac{\$}{Therm} + Hours_{\mathrm{Re}corded} \cdot Power_{Electrical\ Consumed} \cdot \frac{\$}{KWh} \quad [6]$$

While the expenses incurred by the competitors EHP would be:

$$EHP_{Operating\ Cost} = Hours_{\mathrm{Re}corded} \cdot Power_{Electrical\ Consumed} \cdot \frac{\$}{KWh} \quad [7]$$

Electrical consumption by the condenser fans and blower motors is ignored because both units utilize these same air-moving components. Knowing the EHP utilizes roughly one kW in compression for every ton of air-conditioning produced* (electrical power usage is 10kW), the savings of the GHP is obtained by using the following equation:

$$GHP_{Savings} = EHP_{Operating\ Costs} - GHP_{Operating\ Costs} \quad [8]$$

* As found in York Heating and Air-Conditioning Technical Guide: R-410A 10 Ton 60 Hertz (246824-YTG-E-0507)

Because the price of electricity varies with time of year, time of day, and region, the specific utility companies supplying the installations were contacted for rate information. The utility companies supplying electricity to the three regions are Southern California Edison (SCE), Nevada Power Company, and Arizona Public Service Company (APS). The rates charged by these companies are listed in Table 1.

Table 1. Cost of electricity and natural gas for Nevada (Nevada Power), Arizona (APS), and Southern California (SCE).

Las Vegas* Nevada Power		Phoenix† APS		Victorville‡ SCE (Edison)	
LGS-1($/kWh)	$0.085	E32		GS-2	
Demand charge ($/kW)	$2.000	First 200 ($/kWh)	$0.09115	summer ($/kWh)	$0.15154
Facility charge ($/kW)	$3.540	Remaining ($/kWh)	$0.05330	Winter ($/kWh)	$0.14110
Total ($/kW)	$5.540	Demand charge ($/kW)	$8.47700	Demand charge ($/kW)	$9.54000
Southwest Gas		Southwest Gas		Southwest Gas	
G-25($/therm)	$1.03701	G-25($/therm)	$1.12750	G-40 ($/therm)	$1.31863
NOTE: Refer to section 3.5.2 for the results of the comparison.					

3.3 Summary of cooling operation

This section summarizes the reliability, performance and economy of the demonstration GHPs in cooling operation. Davis-Monthan AFB is excluded from performance and economical conclusion due to faulty gas meter readings. With ambient temperatures exceeding 120°F, the gas heat pumps were tried in all facets of the design. This portion of the report will present all results obtained for reliability, performance, and economics.

3.3.1 Cooling mode operating history

The overall units' performances in cooling mode were a success. Care was taken to record all outages with detailed notes on the type, cause, and solution of the failures. These outage statistics are represented as pie charts

* Rates gathered from Nevada Power Company, www.nvenergy.com, 702-402-4300

† Rates gathered from Arizona Public Service Company, www.aps.com, 602-250-1000

‡ Rates gathered from Southern California Edison, www.sce.com, 800-990-7788

as seen in Figure 13 through 19. A timeline of all cooling and heating events causing unit downtime was created to help identify trends and to lessen the difficulty of identifying critical lessons learned in the development of gas cooling. Detailed description of event timeline for the six demo sites can be found in Appendix A.

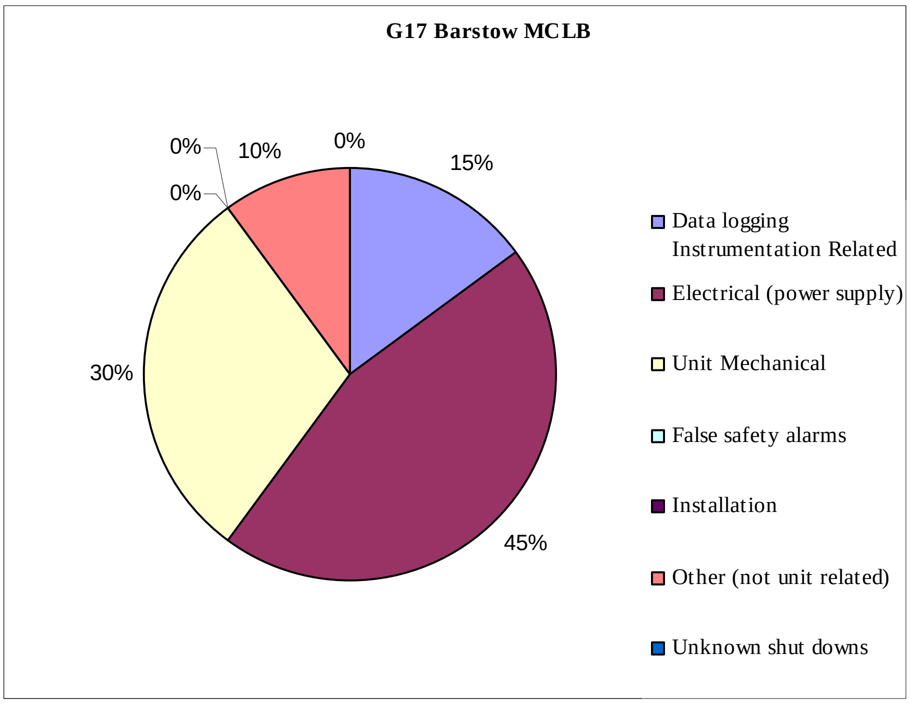

Figure 13. Types of outages for the cooling season at Barstow AFB, Nevada.

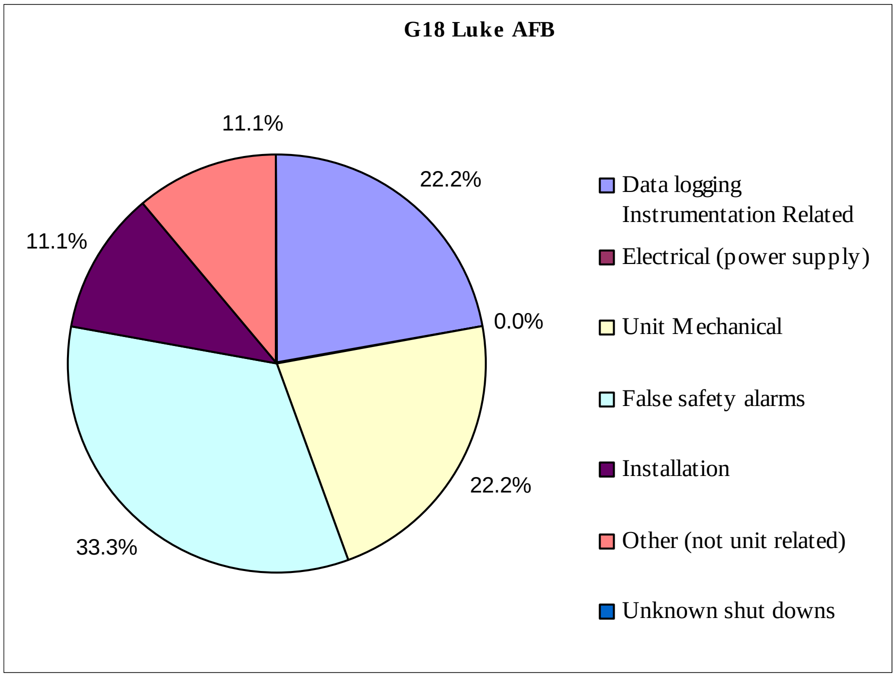

Figure 14. Types of outages for the cooling season at Luke AFB, Arizona.

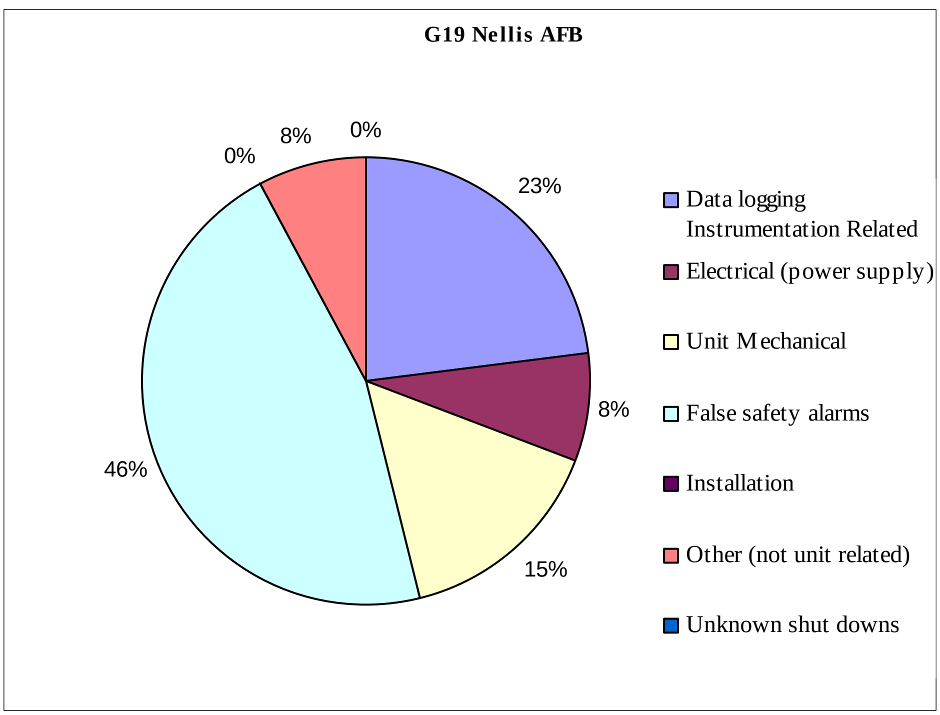

Figure 15. Types of outages for the cooling season at Nellis AFB, Nevada.

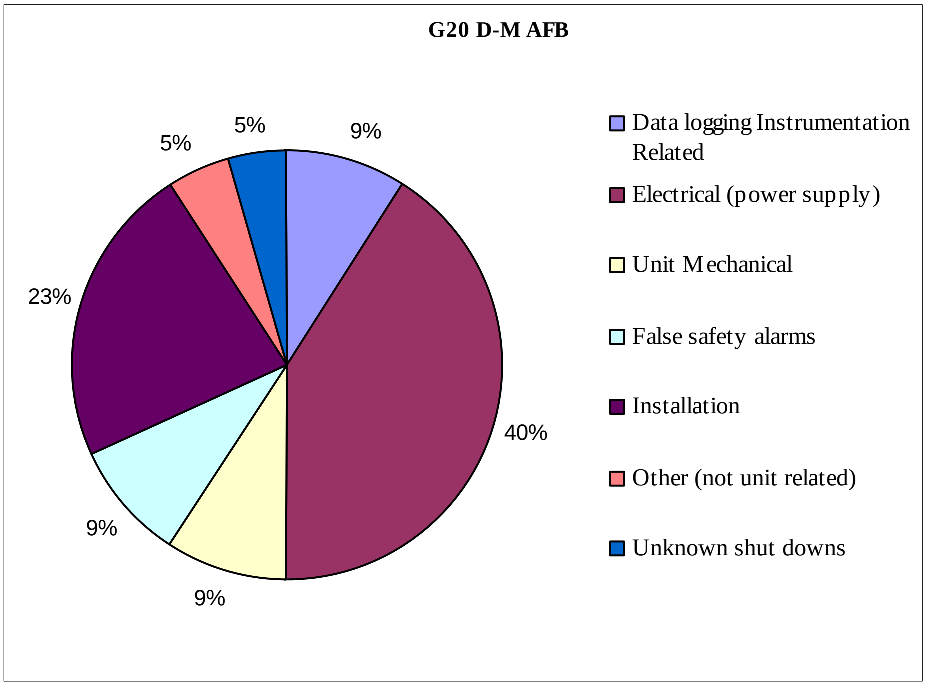

Figure 16. Types of outages for the cooling season at Davis Monthan AFB, Arizona.

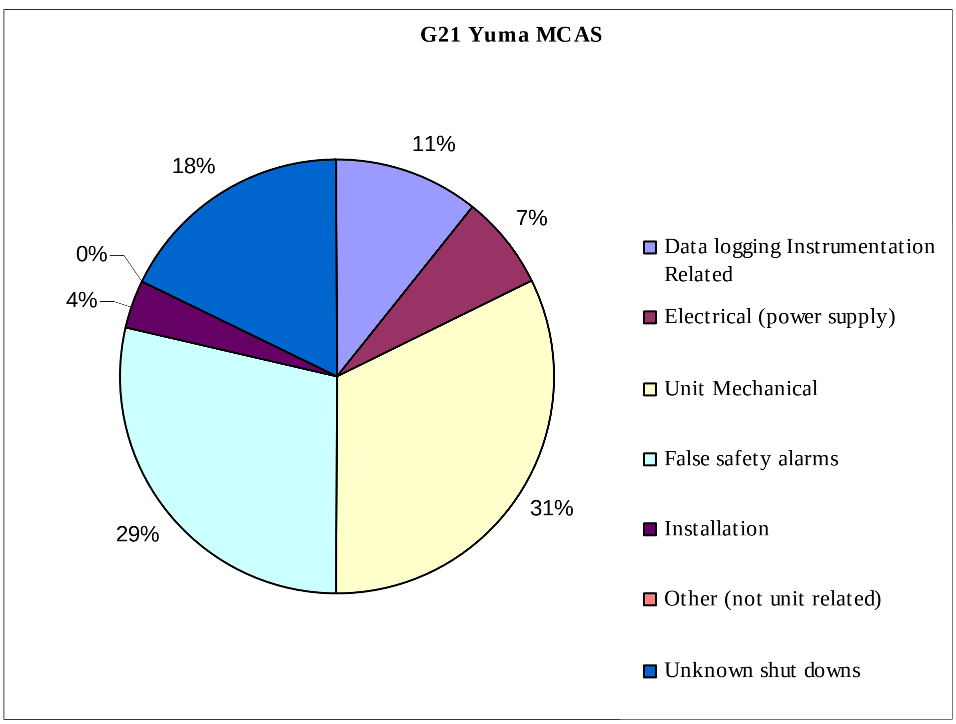

Figure 17. Types of outages for the cooling season at Yuma MCAS, Arizona.

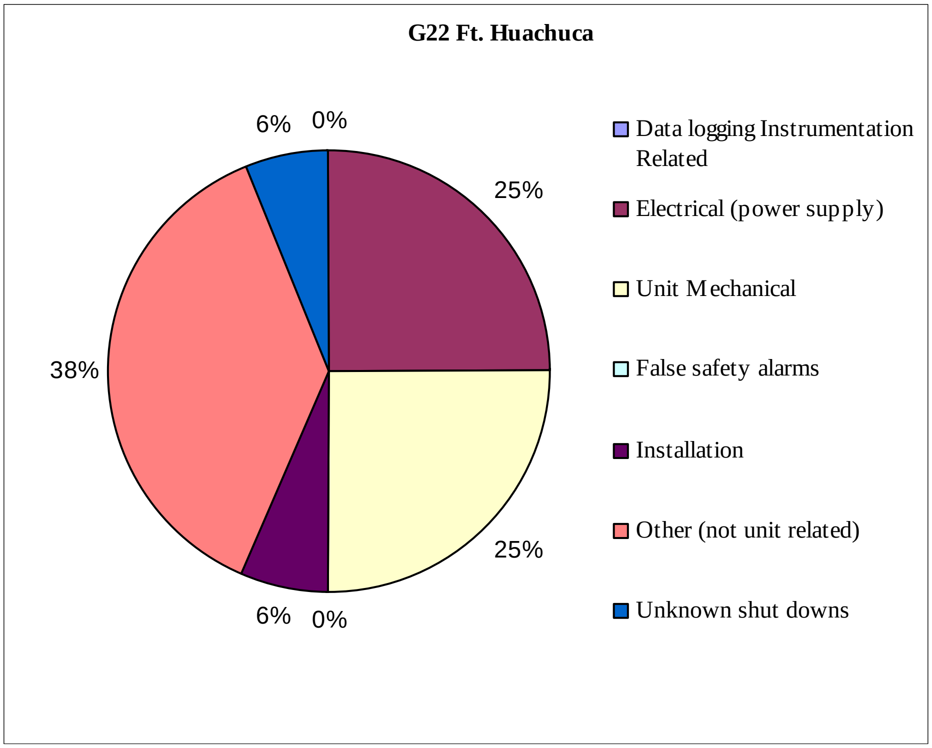

Figure 18. Types of outages as percentages for the cooling season at Fort Huachuca AG, Arizona.

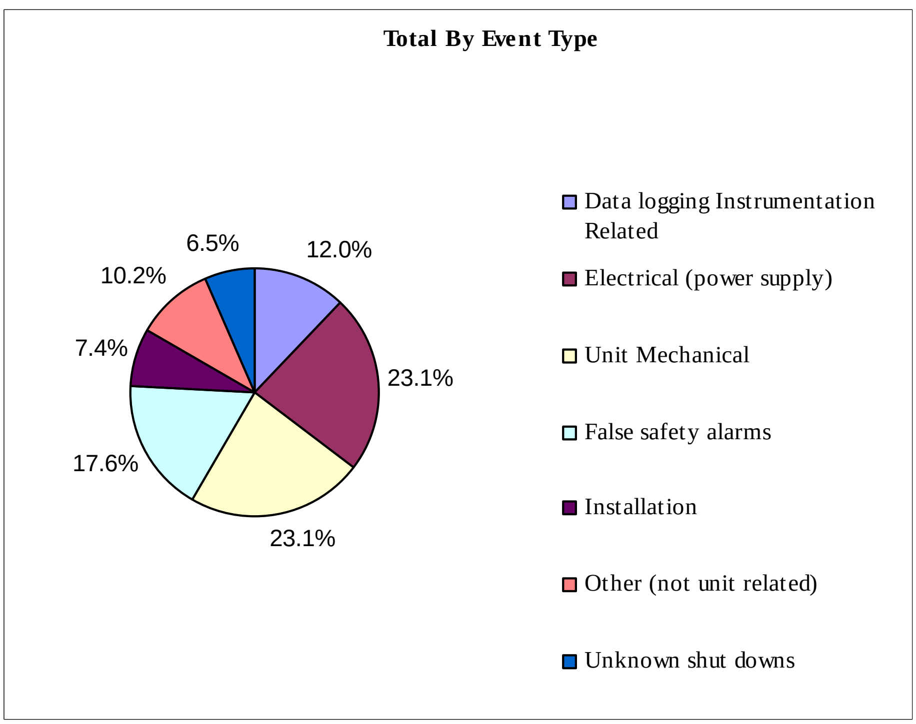

Figure 19. Total events, from all locations, by type for the entire cooling season.

Within the cooling season, major field design changes took place to help assure customers reliability and fix current problems. The major maintenance activities that occurred in the cooling season are listed below.

- Major maintenance activities during Phase I:
  - installed buck-and-boost transformers to help solve power-quality issues
- Major maintenance activities during Phase II
  - installed refrigerant detector to notify occupants of a refrigerant line failure
  - installed phase monitor to protect electrical components
  - sealed engine bulkhead from the indoor section to reduce the possibility of refrigerant entering the indoor section from an engine compartment refrigerant leak (source of line vibration)
  - installed fuses on electrical lines leading to high and low pressure cutouts to act as indicators in troubleshooting unit failures
- Major maintenance activities during Phase III
  - removed capillary tubes to reduce line vibration and mitigate the refrigerant leaks
  - reinstalled and remounted pressure transducers to reduce vibration and mitigate the risk of refrigerant leaks
  - installed headers for safety pressure cutouts and pressure transducers
  - moved oil supply lines to enter the suction accumulator on the low side to prevent excess oil from entering the compressors
  - installed rubber “speedy-boots” on bulkhead/refrigerant line interfaces for sealing issues
  - repositioned outdoor ambient probe
  - replaced coolant pump fittings

The following by-unit summary describes the specific types of failures during the cooling season:

- April 2007
  - GHP 18 (Luke AFB): As the only unit suffering from any type of outage during April 2007, GHP 18 experienced a low-pressure refrigeration failure. This was caused by tenants restricting the indoor air flow with an improper variable air volume (VAV) setting.
  - GHP 20 (Davis-Monthan AFB): Unit was found down by a technician. When the thermostat would call the unit for operation, the en-

gine would fail to start. This problem was caused by power-quality issues.

- May 2007
  - GHP 17 (Barstow MCLB): three power-quality related issues and two refrigerant leaks.
  - GHP 19 (Nellis AFB Installation): outages caused by a refrigerant leak, and a non-unit related power failure.
  - GHP 20 (Davis-Monthan AFB): two refrigerant leaks and three power-quality related outages; phase III upgrades also installed.
  - GHP 21 (Yuma MCAS): refrigerant and gas leak.
  - GHP 22 (Fort Huachuca AG): outages caused by a failed blower motor and power-quality issues.
- June 2007
  - GHP 17 (Barstow MCLB): third major refrigerant leak occurred; as a result of the internal refrigeration system being exposed to the atmosphere multiple times, the thermostatic expansion valve (TXV) began to malfunction.
  - GHP 18 (Luke AFB): during previous month, Phase III upgrades were installed; system this month experienced a single outage caused by shorted refrigerant alarm wires.
  - GHP 19 (Nellis AFB): all failures this month were caused by false refrigerant alarms.
  - GHP 21 (Yuma MCAS): Phase III upgrades were installed this month; unit also experienced a single outage from a loose relay.
  - GHP 22 (Fort Huachuca AG): purposely shutdown for the Phase III installation.
- July 2007
  - GHP 18 (Luke AFB): experienced outages resulting from a malfunctioning expansion valve and a refrigerant detector false alarm. The expansion valve issues were caused by poor oil-flow management.
  - GHP 20 (Davis-Monthan AFB): two phase protectors failed; both had to be replaced.
  - GHP 21 (Yuma MCAS): after a refrigerant leak detector was installed, it caused numerous false alarms, shutting the unit down on a fault.
  - GHP 22 (Fort Huachuca): experienced two outages thought to be caused by electrical supply power-related issues.

- August 2007
  - GHP 17 (Barstow MCLB): coolant leaks began to manifest at the coolant pump's suction connection. Additionally, after the TXV was replaced a month prior, it began to produce oscillating pressure from partial-load conditions. It was concluded this odd behavior originated from excess oil entering the system.
  - GHP 19 (Nellis AFB): power supply for the data acquisition equipment was shorted from rain due to a poorly-sealed door on the GHP.
  - GHP 20 (Davis-Monthan AFB): experienced an outage from a failure to start. This was caused by loose starter wires.
  - GHP 21 (Yuma MCAS): suffered numerous outages caused by a malfunctioning TXV. As with the other units, the oscillating superheat behavior was caused by poor oil-flow control. Additionally, the unit suffered outages from loose wiring.
  - GHP 22 (Fort Huachuca AG): suffered outages caused by a malfunctioning expansion valve and shorted wiring on the starter relay. The TXV was malfunctioning from poor oil control, allowing excess oil to enter the system.
- September 2007
  - GHP 17 (Barstow MCLB): coolant leaks began to manifest at the pump's suction connection. Additionally, after the TXV as replaced a month prior, it began to produce oscillating pressures during part-load conditions. It was concluded this odd behavior originated form poor oil-flow control. This unit also lost its data-gathering capabilities from a technician opening the indoor section during a rain storm.
  - GHP 19 (Nellis AFB): no outages occurred.
  - GHP 20 (Davis-Monthan AFB): as the indoor temperatures and load began to drop in September, the indoor coils froze multiple times. The freezing occurred from inadequate ducting.
  - GHP 21 (Yuma MCAS): experienced a false safety shutdown from a loose connection on the HPCO.
  - GHP 22 (Fort Huachuca AG): LPCOs from the malfunction expansion valve continued to result in shutdowns.
- October 2007
  - GHP 17 (Barstow MCLB): all refrigerant oil was replaced while the oil return line was rerouted (part of Phase III upgrades).

  - GHP 19 (Nellis AFB): a coolant leak was found from a crack in the coolant pump. It was also noticed that the circuit B HPCO started to leak while rust was developing in the condensate pan.
  - GHP 20 (Davis-Monthan AFB): indoor coil continued to freeze from faulty ductwork.
  - GHP 22 (Fort Huachuca AG): experienced one outage caused by a failed starter diode.
- November 2007
  - GHP 17 (Barstow MCLB): a refrigerant hose began to leak in the indoor compartment. To reduce leak-causing vibration, the discharge lines were rigidly attached to the bulkhead.
  - GHP 19 (Nellis AFB): experienced an outage caused by a failed blower bearing.
  - GHP 20 (Davis-Monthan AFB): ductwork was examined and new design concepts were initiated.

3.3.2 Cooling mode performance summary

With an average outdoor temperature of 79˚F, the gas-packaged heat pumps produced an average unit COP of 1.33, an average capacity of 83,418 Btu/hr and an average fuel consumption of 63,056 Btu/hr. Individually, the GHP located at Barstow MCLB generated the greatest unit COP of 1.55, while the unit located at Yuma MCAS produced the smallest unit COP of 0.97. Davis-Monthan AFB was not included in the performance analysis because of a malfunctioning fuel meter. The performance details of all individual units are located in Table 2 and Figure 20.

Table 2. Cooling season performance summary 01 June 2007 to 01 October 2007.

Unit	Total Therms	Total Hours	Average Fuel Consumption (Btu/hr)	Average Power Consumption (W)	Airside Capacity (Btu/hr)	Airside Unit COP	Airside System COP	Average Outdoor Temp. (˚F)	Max Outdoor Temp. (˚F)
G17 Barstow MCLB	2245	3491	64308	2683	99805	1.55	1.36	80	124
G18 Luke AFB	1233	2247	54873	2313	83032	1.51	1.32	85	119
G19 Nellis AFB	851	1456	58448	2279	83440	1.43	1.26	81	120
G20 Davis-Monthan AFB*	1634	1650	80626	2318	122863	1.53	1.39	89	111
G21 Yuma MCAS	1682	2273	73999	2132	71731	0.97	0.88	81	113
G22 Fort Huachuca AG	1149	1913	60063	2896	65866	1.10	0.94	70	98
Average	1466	2172	63056	2417	83418	1.33	1.18	79	114

* Data from Davis Monthan AFB is based on two months data during June-July 2007.

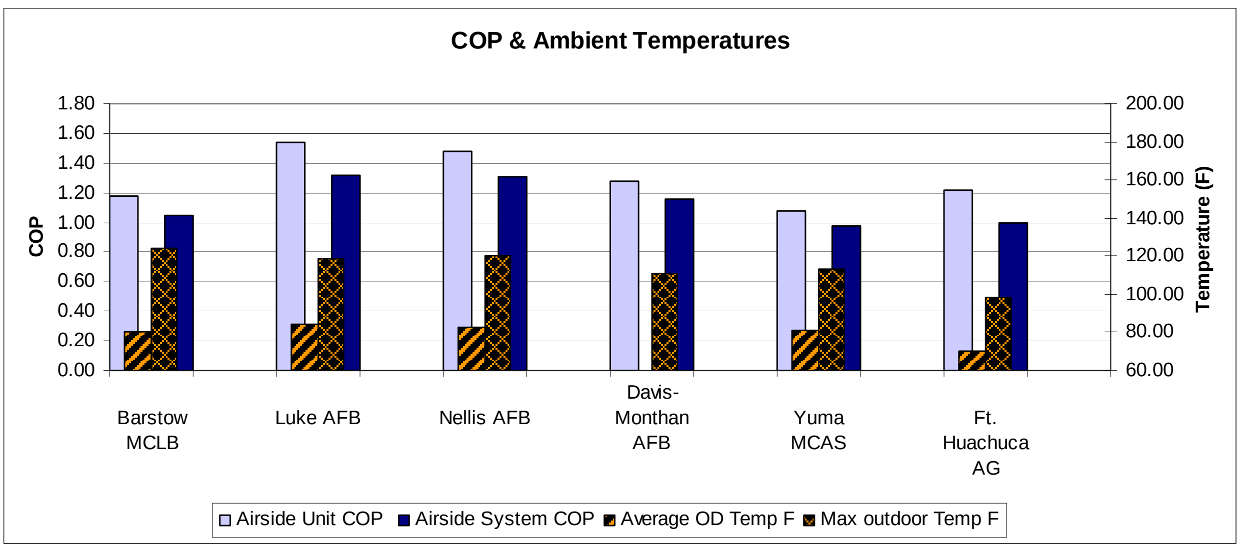

Figure 20. Maximum temperatures, average temperatures, and COPs on a by-unit basis.

As seen in Table 2, the units located at Yuma MCAS and Fort Huachuca AG showed the lowest efficiencies of the group. For Fort Huachuca AG, this lower efficiency is explained by faulty ductwork, which forced the unit to run excessively on high speed because the conditioned air lacked a properly ducted path to the climate-controlled area. By the time the thermostat sensed the referenced temperature, the unit had already cooled the attic before dropping the temperature of the living space. Compounding the reasons for low efficiency, Fort Huachuca also resides in a much higher elevation than the other units, which forces the carbureted motor to consume more fuel. In addition, the Yuma MCAS installation also had a low COP of .97. The Yuma unit cooled a warehouse where large garage doors were opened daily, requiring the unit to continually run on high speed during high ambient temperature conditions.

Although two of the six units produced less than expected efficiencies, the other four demonstration units supplied valuable information pertaining to their ability to operate in high ambient temperature applications. By using correlated fuel values obtained from testing at Oak Ridge National Labs (Zaltash et al. 2007), the instantaneous fuel consumption was obtained (as a function of ambient temperature and engine speed). This function was then used to obtain by-minute COPs. Using the Nellis AFB installation as an example, one can see in Figure 22 that the unit generated COPs of approximately 1.1 at 120°F outdoor temperatures. In addition to the COPs, by-minute data regarding outdoor temperature, airside capacity, and fuel usage were also displayed in graphical form. By examining Figure 23, one can see how the fuel usage and airside capacity behave as afternoon temperatures increase. This particular location proves that the GHPs are capable of capacities in excess of 100,000 Btu/hr when ambient temperatures exceed 115 °F. One will also notice the capacity only degrades 16.7% as temperature increases from 70 °F to 100 °F, which results in a COP reduction of 32%. The trend-lines in Figure 21 can be expressed by the following equations:

$$\text{Capacity (ambient temperature)} = -351\cdot(\text{ambient temperature})+111{,}766 \qquad [9]$$

$$\text{Fuel Consumption (ambient temperature)} = 281\cdot(\text{ambient temperature})+33{,}323 \qquad [10]$$

$$\text{COP (ambient temperature)} = -0.0135\cdot(\text{ambient temperature})+2.62 \qquad [11]$$

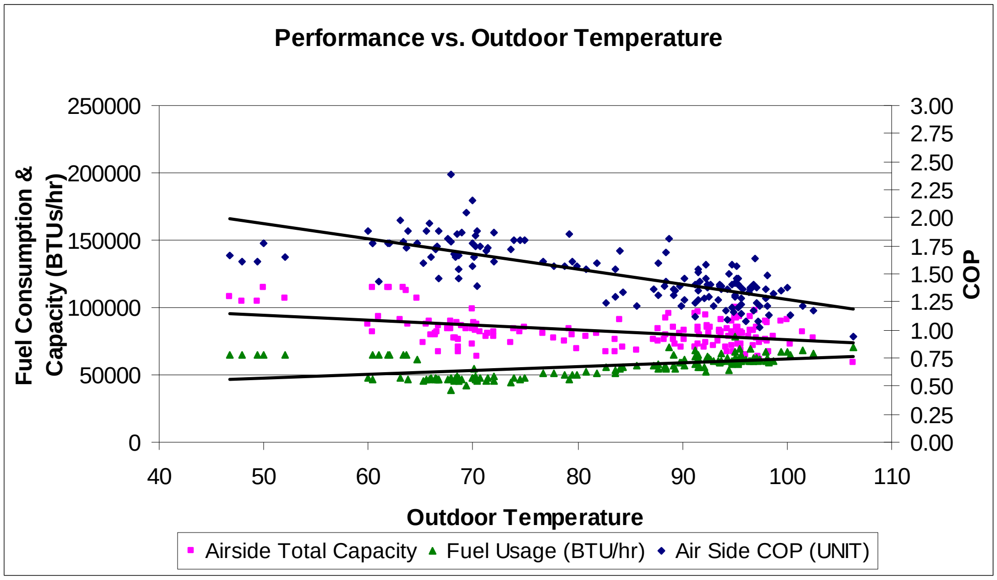

Figure 21. Linear correlations representing the minimal degradation of efficiency as outdoor temperatures increase.

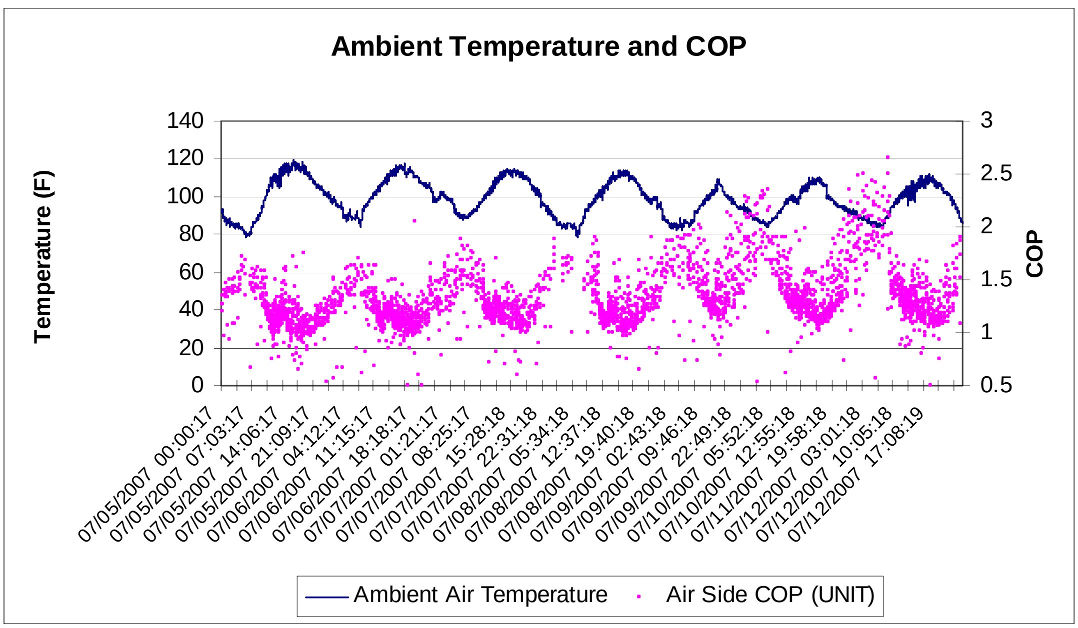

Figure 22. Typical COP and outdoor air temperatures during the hottest time of the year; taken form GHP 19 (Nellis AFB) during early July 2007.

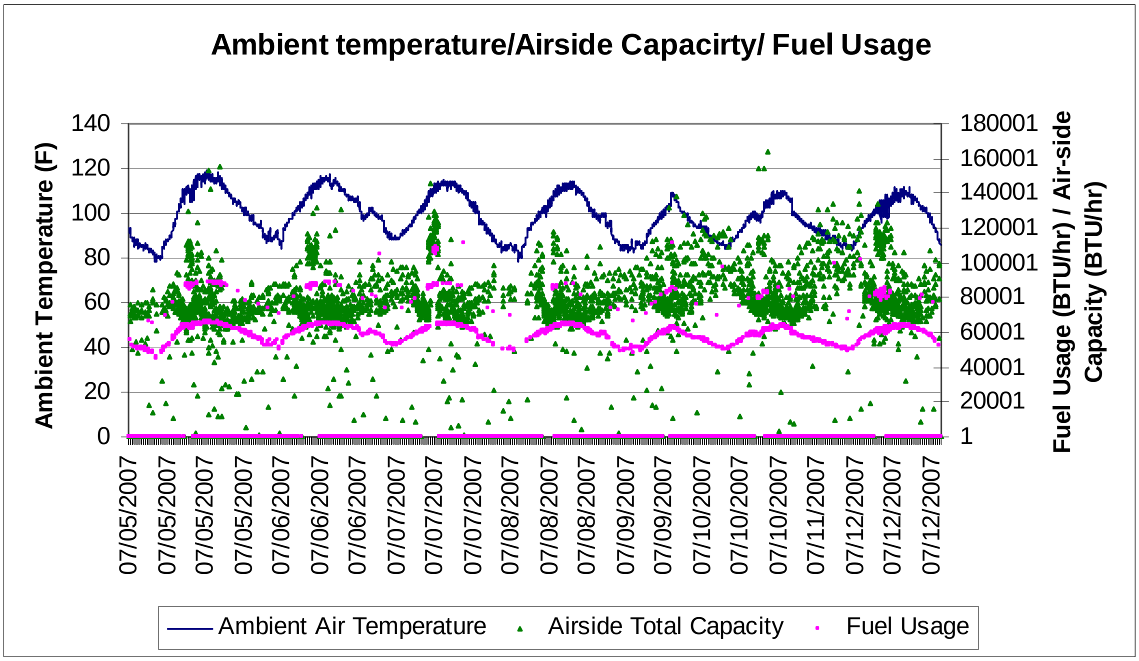

Figure 23. Shows how the GHP is capable of maintaining large capacities during high-ambient conditions with varying engine speeds and fuel consumption rates.

3.3.3 Cooling mode savings

Once the cooling season was completed, an economic analysis was conducted which compared the operation of an electric heat pump (EHP) with the demonstrated GHP prototype. The comparison was made with a high-efficiency York Model XP120 EHP. It was appropriate to use this particular EHP for comparison because it has the dual circuits and partial-load capabilities, similar to the GHP. The savings incurred with various electrical rates are presented in the following table:

Table 3. Summary of operating cost for the six GHP installations during cooling season.

Unit	Natural Gas	Power	Total
GHP operating cost per site.			
Barstow MCLB	$2,960	$1,573	$4,533
Luke AFB	$1,390	$868	$2,259
Nellis AFB	$882	$359	$1,241
Davis-Monthan AFB	$1,842	$733	$2,575
Yuma MCAS	$1,896	$808	$2,705
Fort Huachuca AG	$1,295	$948	$2,243

Unit	Natural Gas	Power	Total
EHP operating cost per site			
Barstow MCLB	$0	$6,077	$6,077
Luke AFB	$0	$3,920	$3,920
Nellis AFB	$0	$1,668	$1,668
Davis-Monthan AFB	$0	$3,044	$3,044
Yuma MCAS	$0	$3,959	$3,959
Fort Huachuca AG	$0	$3,430	$3,430
GHP cooling operating cost savings			
Unit	Operating Cost ($)		Operating Cost (%)
Barstow MCLB	$1,543		25%
Luke AFB	$1,662		42%
Nellis AFB	$427		26%
Davis-Monthan AFB	$469		15%
Yuma MCAS	$1,254		32%
Fort Huachuca AG	$1,187		35%

3.4 Summary of heating operation

This section provides results for the heating-performance and maintenance-duty summaries for the DoD demonstration GHPs.

3.4.1 Heating mode operating history summary

Throughout the heating season, particular care was taken to record the durations and causes for all outages. The pie charts in Figures 24–30 were created to reveal particular problem areas for the units during heating operation.

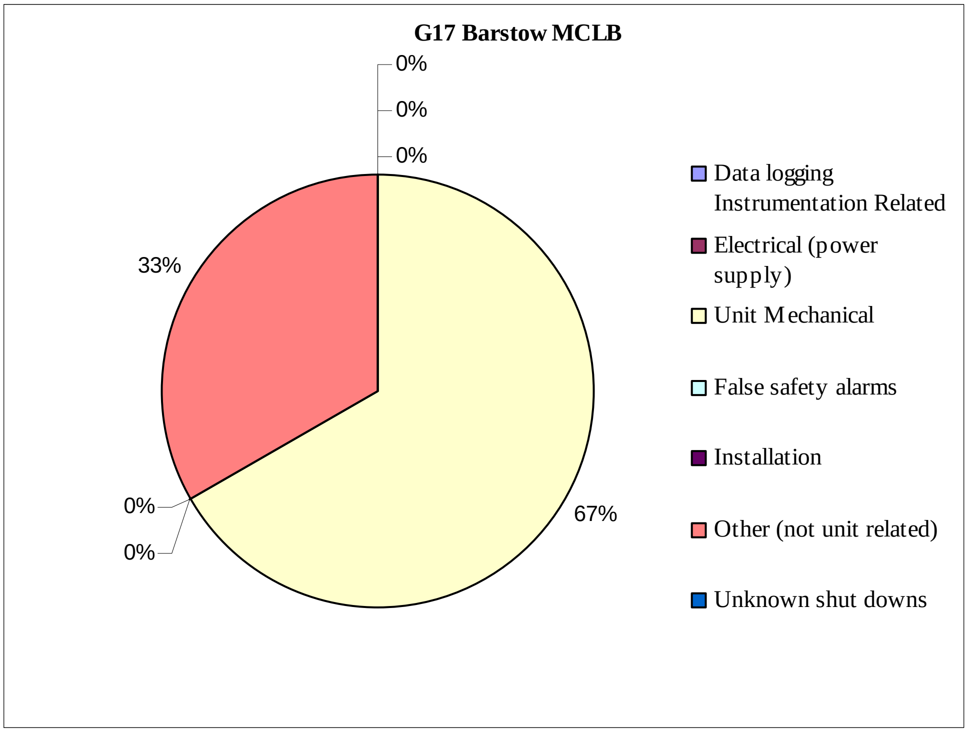

Figure 24. Types of outages for the heating season at Barstow MCLB, Arizona.

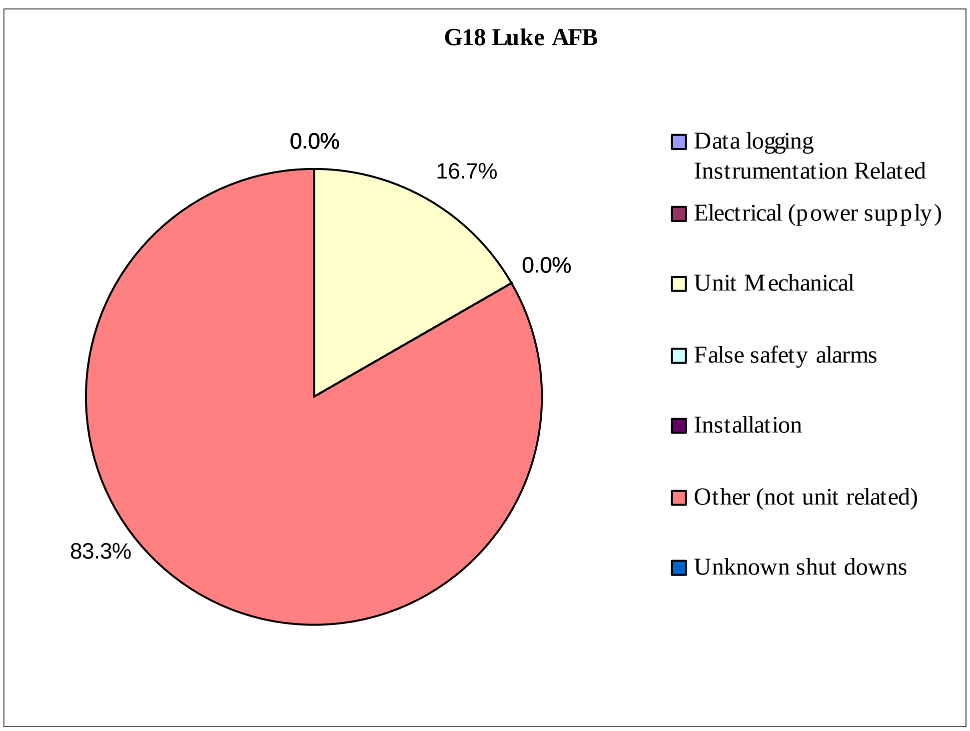

Figure 25. Types of outages for the heating season at Luke AFB, Arizona.

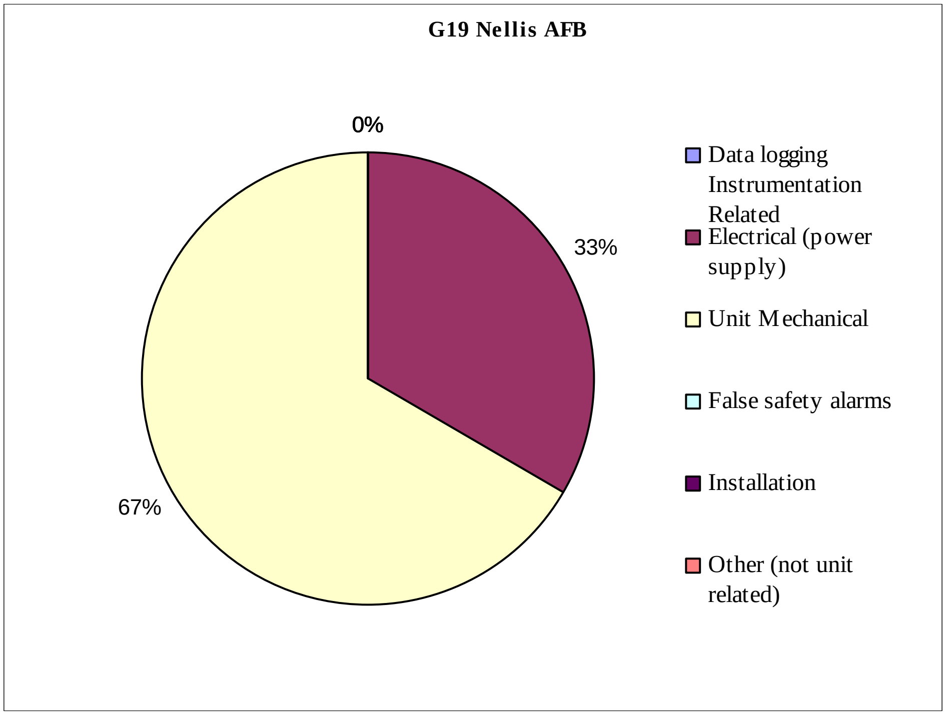

Figure 26. Types of outages for the heating season at Nellis AFB, Nevada.

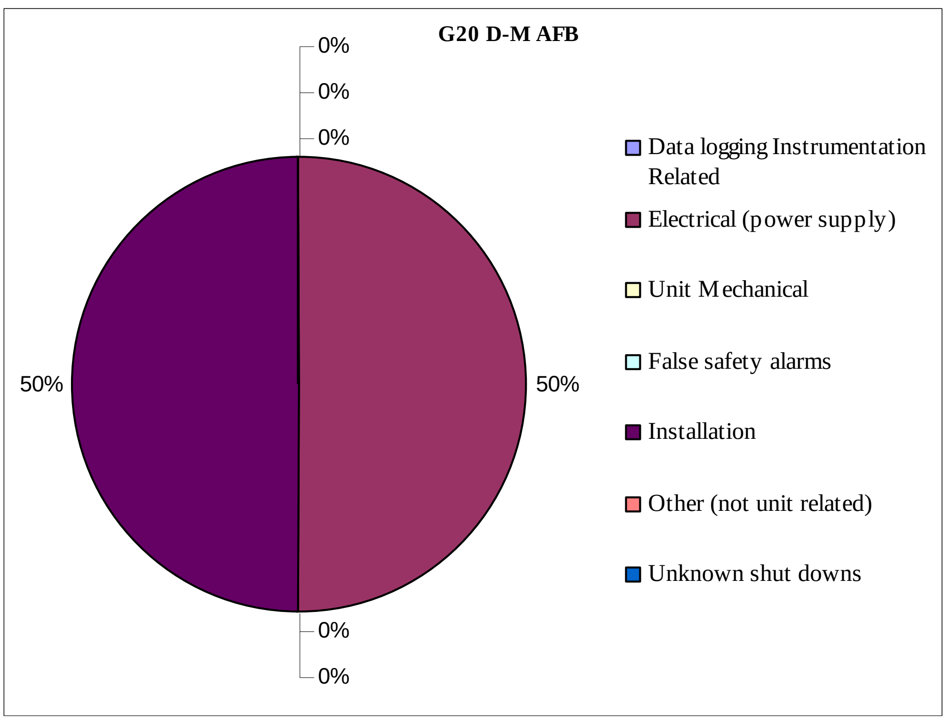

Figure 27. Types of outages for the heating season at Davis-Monthan AFB, Arizona.

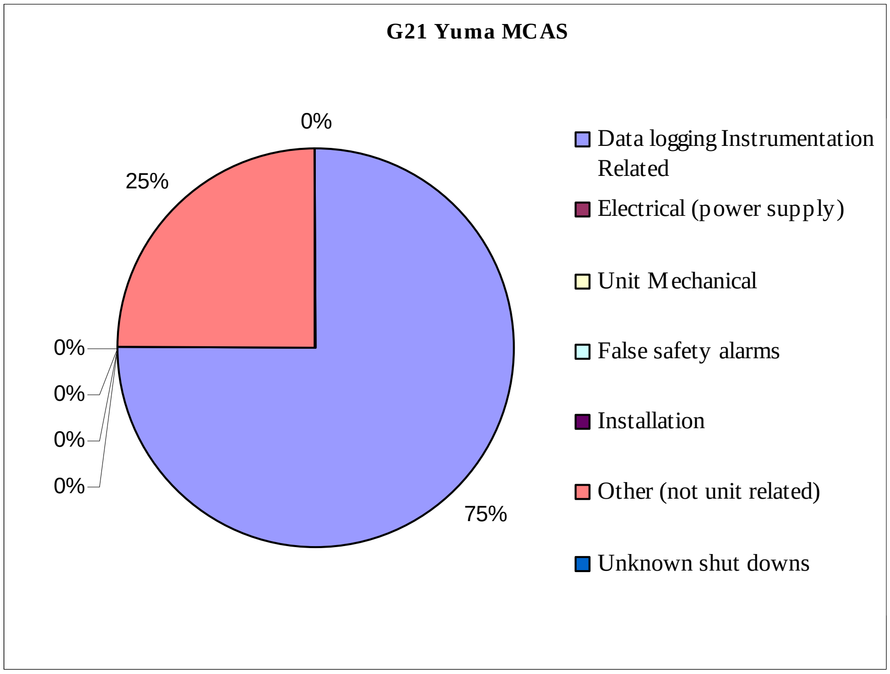

Figure 28. Types of outages for the heating season at Yuma MCAS, Arizona.

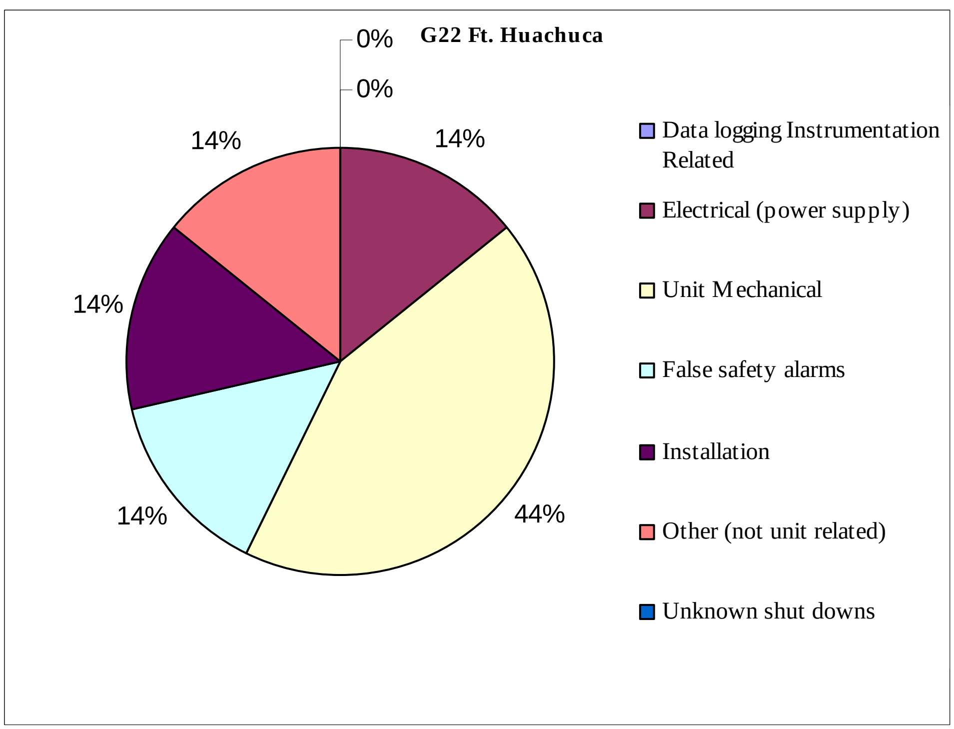

Figure 29. Types of outages for the heating season at Fort Huachuca AG, Arizona.

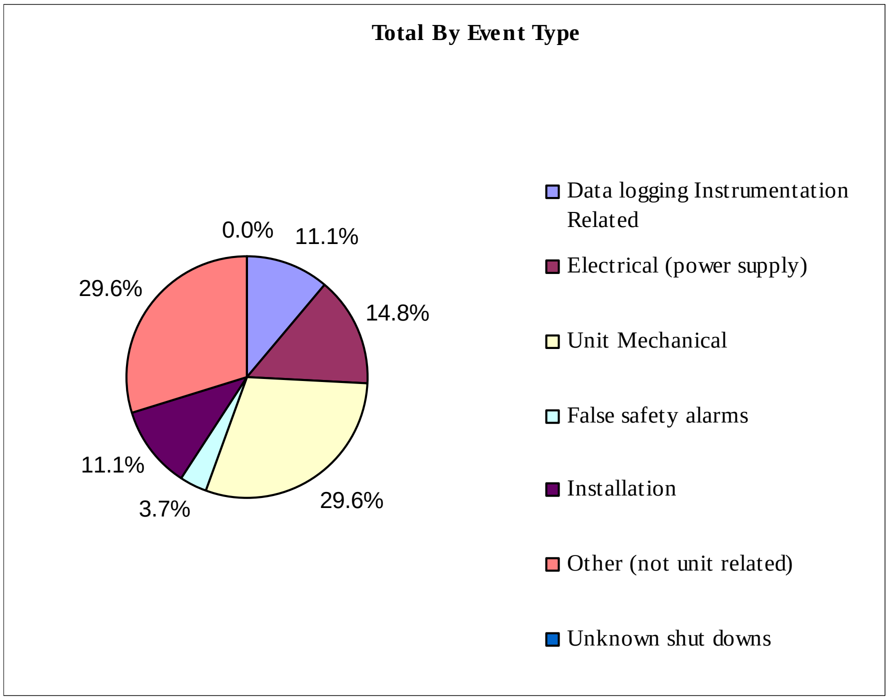

Figure 30. Total of outage causes for the entire heating season, all locations.

It should be stressed that many of these issues dealt with improperly installed check valves, inadequate refrigerant charges, and failed blower motors from faulty belt installations. After eliminating these problems related to contractor maintenance duties, the units exhibited an impressive reliability history. To supply a general monthly-outage summary to the reader, the following list of monthly outages was created for the heating-season, on a by-unit basis.

- December 2007
    - *GHP 18 (Luke AFB)*: upon arrival, technicians noticed a low pressure cut-out (LPCO) was blown. GHP 18 continually showed this type of behavior in heating throughout December and January, which persuaded the engineering department to reclaim the entire refrigeration system and proceed with a fresh charge of refrigerant. After this change, the unit displayed an impressive maintenance history.
    - *GHP 19 (Nellis AFB)*: suffered from a failed blower motor, causing the system cutout on a high pressure cutout (HPCO).
    - *GHP 20 (Davis-Monthan AFB):* suffered from a shutdown resulting from indoor airflow conditions. The ductwork for this applica-

tion was only designed for a 5-ton system, causing an HPCO. After these ductwork findings, it was determined to run the unit only on low-speed heating with one compressor.
    - *GHP 21 (Yuma MCAS)*: also suffered from a minor gas leak in the line leading to the roof.
- January 2008
    - *GHP 17 (Barstow MCLB)*: conducting monthly repairs with typical data acquisition maintenance, the unit was down for 16 hours.
    - *GHP 22 (Fort Huachuca AG)*: suffered from a failed blower motor, allowing excessively-high head pressures to manifest. The cause of the failed motor was excessive belt tension.
- February 2008
    - *GHP 20 (Davis-Monthan AFB)*: experienced an outage thought to be caused by a type of power failure. Data gathered did not provide any clues to this failure, resulting in over 300 hr of lost operation.
    - *GHP 22 (Fort Huachuca AG)*: suffered outages from remaining refrigerant alarm sensors and possible power issues. Additionally, the unit was shut down for 2 weeks to allow for ductwork replacement.
- March 2008
    - *GHP 18 (Luke AFB)*: experienced an outage from a failed blower motor. The lack of indoor airflow caused the HPCO to trip.
    - *GHP 19 (Nellis AFB)*: a blower belt was improperly installed on GHP 19, causing the unit to shutdown from a LPCO in cooling operation.

3.4.2 Heating-mode performance summary

Examining the heating season of December 2007–March 2008 provided data for capacity and efficiency conclusions. During that period, the average outdoor air temperature was 51˚F, with the coldest extreme temperature of 21˚F occurring at the Fort Huachuca AG installation. After examining the data recorded during these test conditions, the gas units produced an accumulative unit COP of 1.4. The highest monthly COP of 1.6 occurred at Davis-Monthan AFB, while the lowest COP of 1.1 happened at Fort Huachuca. Davis-Monthan was included in this analysis because the gas meter began reading correctly during the heating season.

Although these units had a few times of cooling operations, these DoD units generally operated in heating. The cumulative performance data for the heating season follows in Table 4 and Figure 31.

Table 4. Heating season performance summary, November 2007–March 2008.

Unit*	Total Therms	Total Hours	Average fuel Consumption (Btu/hr)	Average Power Consumption (W)	Airside Capacity (Btu/hr)	Airside Unit COP	Airside System COP	Average Outdoor Temp. (˚F)	Minimum Outdoor Temp. (˚F)
G17 Barstow MCLB	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G18 Luke AFB	242	500	48400	3149	69832	1.44	1.18	55	30
G19 Nellis AFB	79	173	45428	2223	67387	1.48	1.27	50	26
G20 Davis-Monthan AFB	563	1207	46633	2738	72809	1.56	1.30	52	28
G21 Yuma MCAS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G22 Fort Huachuca AG	1817	2795	64990	3715	69058	1.06	0.89	49	21
Average	675.25	1169	51362	2956	69772	1.36	1.14	52	26

*Yuma MCAS was not included because it was restricted from running in heating (there was no heating demand).

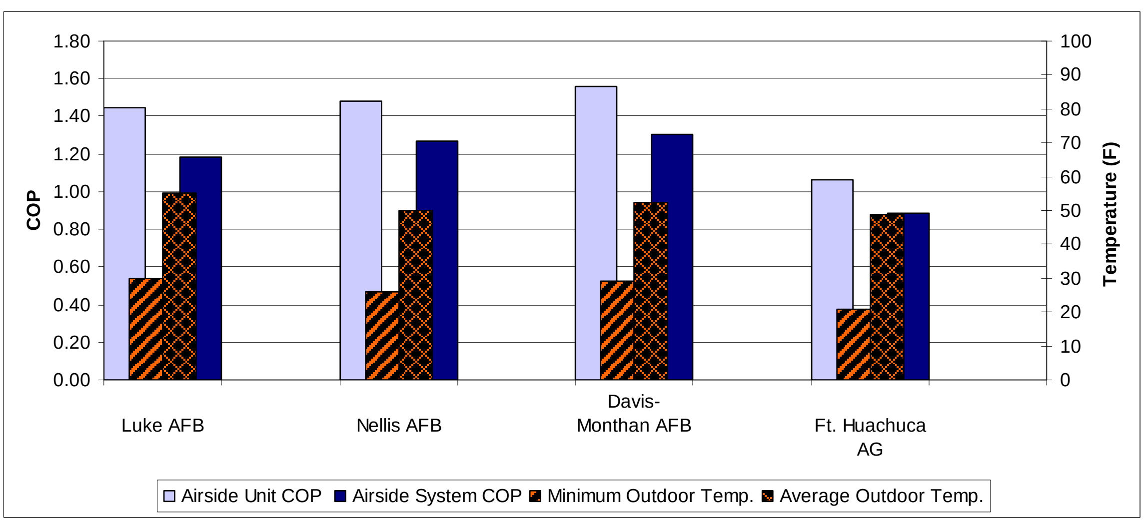

Figure 31. Maximum temperatures, average temperatures, and COPs on a by-unit basis for the heating season.

The units produced promising efficiencies. Compared to the cooling season, theses increased efficiencies originate from the basic physics associated with a heat pump operating in heating mode, coupled with heat recovery technologies. Figure 32 and Figure 33 represent the benefits associated with heat recovery.

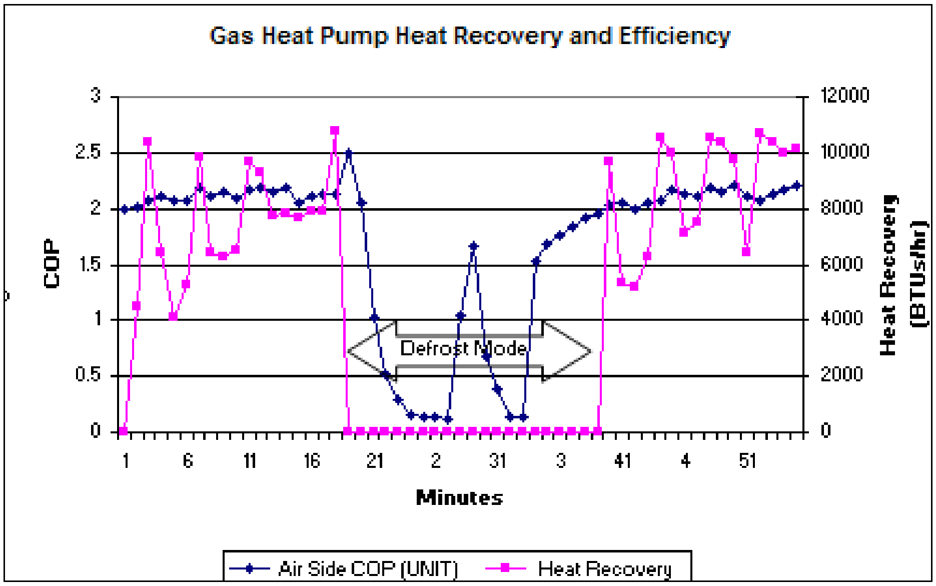

Figure 32. Fort Huachuca installation data taken from January 2008, showing the benefits associated with the gas heat pump's heat recovery capability.

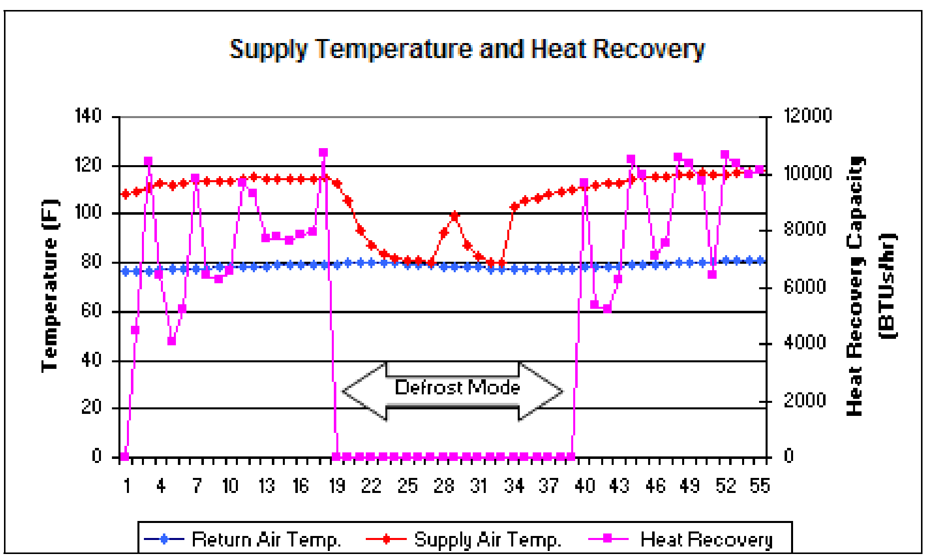

Figure 33. Fort Huachuca installation data taken from January 2008, showing the benefits associated with the gas heat pump's heat recovery capability.

As seen in the above figures, the heat recovery technology allows the unit to achieve a COP greater than 2.0, with supply air temperatures in excess of 115˚F. Additionally, Figures 32 and 33 also show how a constant indoor temperature is maintained during defrost mode.

3.4.3 Heating mode savings

Using the total fuel usage from manual gas meter readings and total run time from each unit, the annual heating mode saving was calculated and compared to a high-efficiency EHP. The resulting savings are shown in Table 5.

Table 5. Summary of GHP operating cost per site for the six DoD installations during heating season.

Unit	Natural Gas	Power	Total
Barstow MCLB	$989	$640	$1,628
Luke AFB	$273	$388	$660
Nellis AFB	$82	$107	$189
Davis-Monthan AFB	$635	$617	$1,251
Yuma MCAS*	*	*	*
Fort Huachuca AG	$2,049	$1,364	$3,412
EHP operating cost per site			
Unit	Natural Gas	Power	Total
Barstow MCLB	$0	$2,179	$2,179
Luke AFB	$0	$1,132	$1,132
Nellis AFB	$0	$442	$442
Davis-Monthan AFB	$0	$2,072	$2,072
Yuma MCAS	$0	$0	$0
Fort Huachuca AG	$0	$4,182	$4,182
GHP heating operating cost savings			
Unit	Operating Cost ($)	Operating Cost (%)	
Barstow MCLB	$551	25%	
Luke AFB	$472	42%	
Nellis AFB	$253	57%	
Davis-Monthan AFB	$821	40%	
Yuma MCAS	*	*	
Fort Huachuca AG	$770	18%	
*Yuma MCAS was not included because there was no heating demand.			

As shown in the above table, the Nellis AFB Installation produced minimal savings during the heating season. This is primarily caused by the low run times seen at the Nellis and Luke AFB installations. Additionally, many of the units experienced short-cycle behavior, inhibiting the unit from reaching the steady-state condition required for the utilization of heat recovery.

3.5 Combined reliability and economy summary

This section provides a comprehensive summary for the reliability and performance outcomes during both heating and cooling operations.

3.5.1 Heating and cooling reliability summary

Considering the faulty ductwork and invasive data acquisition techniques, the units' overall operation was a success. The outages provided valuable knowledge for improving future designs. As shown in Figure 34, the units at each site were operational over 90% of the time. Figure 35 depicts the unit run hours by site. The unit in Barstow ran the most (5,093 hr) while the Nellis AFB installation ran the least (1,866 hr). Also shown in Figure 35, the units accumulated a run time total 19,526 hr.

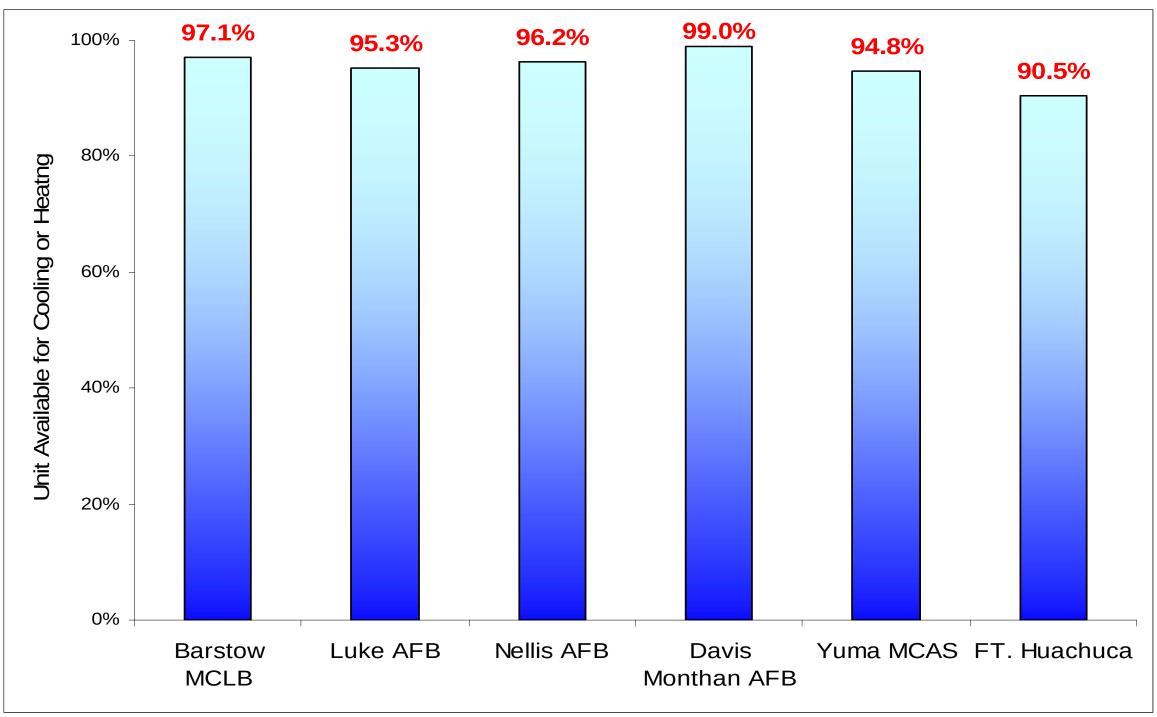

Figure 34. Percentage of time unit available for operation by site.

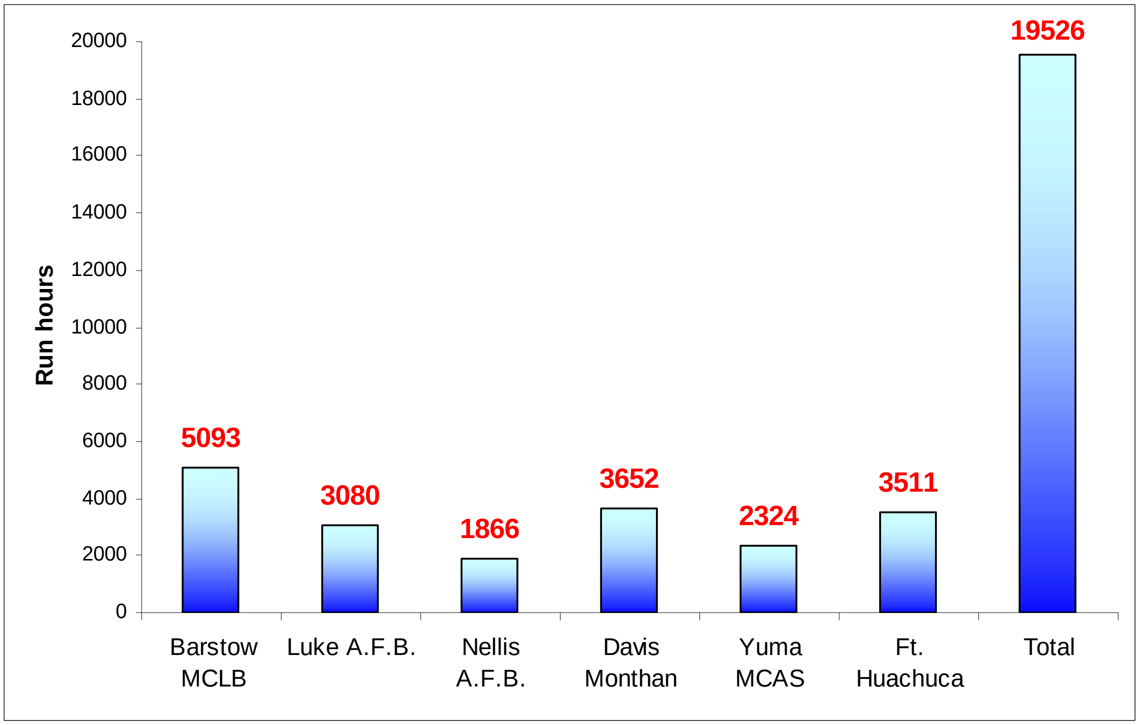

Figure 35. Unit run hours by site, and accumulated total.

Figure 36 illustrates the overall unit operation in terms of “unit run hours” (meaning the thermostat was calling for either cooling or heating operation, and the unit provided); “available, but demand satisfied” (meaning the thermostat was not calling for either cooling or heating, but the unit was available for operation); and “unit unavailable” (meaning the unit was down due to either safety/preventive shutdowns or maintenance was being conducted at the facility, such as duct repair).

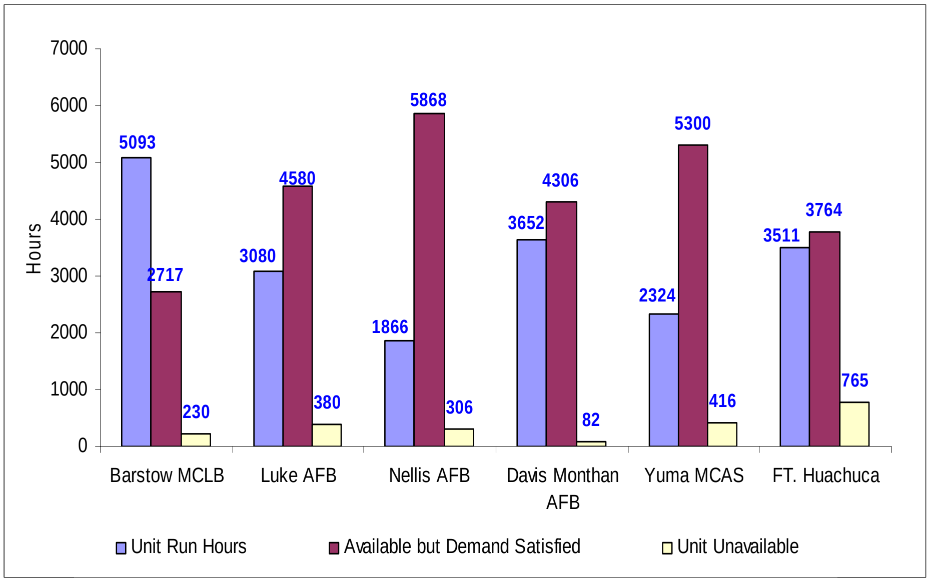

Figure 36. Total operational and non-operational hours by site.

Corresponding to the above operable runtimes, Table 6 and Figure 37 depict the type and frequency of outages.

Table 6. Total number of outages by event type at each site.

	Data logging or Instrumentation Related	Power Supply	Unit Mechanical	False safety alarms	Installation	None Unit-Related	Unknown shut downs	Total
Barstow MCLB	4	3	4	0	0	1	0	12
Luke AFB	2	0	5	2	2	2	2	15
Nellis AFB	4	2	4	3	0	1	0	14
D-M AFB	2	10	4	2	0	1	1	20
Yuma MCAS	3	4	7	4	1	1	6	26
Fort Huachuca	0	4	3	1	2	6	1	17
Total	15	23	27	12	5	12	10	104

In addition to tracking the amount and frequency of outages, the percent contribution of all outages by type for the entire test are calculated and displayed in Figure 37. This figure was created to identify the design or testing aspects of the project that need further development.

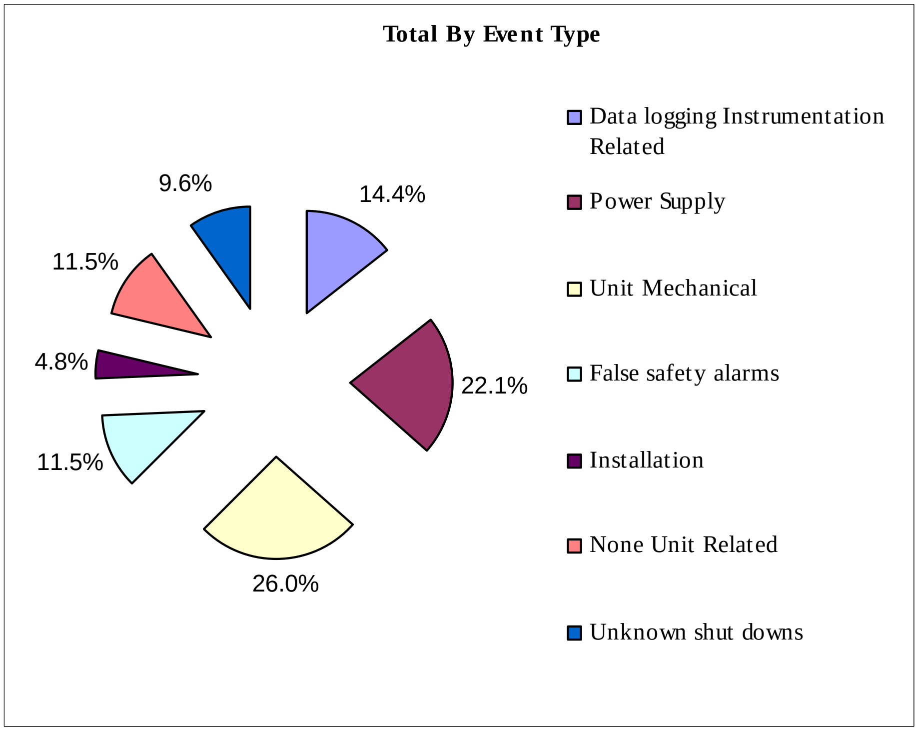

Figure 37. Total outages for all sites, by event causes during the entire testing period.

As shown, mechanical event types accounted for 26% of the total events, followed by electrical power supply issues at 22.1% and false safety alarms at 14.4%. Most mechanical-related issues arose from low suction pressure, due to clogged expansion valve. The causes of these suction events were the result of system exposure to moisture and contaminants during upgrades in the field. During the first few months of operation, several unit failures occurred due to vibration of pressure transducer capillary tubes (related to data-logging instrument). This vibration caused the capillary tube to break, dumping the system's charge and exposing the system to the environment. Proper procedures were not followed during maintenance, leading to contaminants permanently residing within the system. This was resolved by replacing the suction filter, filter drier, and oil strainers, then completely evacuating the system down to 500 microns before recharging it. Additionally, indoor motor and pump problems contributed to the mechanical failures. As for electrical problems, poor power quality at the bases was one of the main issues encountered during the demonstration period. This problem was resolved by adding a "buck-and-boost" transformer. Despite classifying the multiple refrigerant leaks as mechanical, the leading cause of failures had little to do with the actual mechanical design of the thermal system. A record of outages used to create the above reliability table graph is shown in Table 7, spanning the next few pages.

Table 7. Detailed listing of all events observed (by unit) and the repairs made at the six GHP installations throughout the testing period.

Unit	Location	Event Date	U.O.	Repairs	Remarks
GHP 17	Barstow MCLB	5/13/2007	Refrigerant leak resulting from a broken capillary tube (Comp. B)	Repaired broken capillary tube and recharged refrigerant (20 lb)	
GHP 17	Barstow MCLB	5/15/2007	Engine fails to crank (unknown reason)	Reset and restarted unit	Thought to be caused by electrical power quality
GHP 17	Barstow MCLB	5/18/2007	The unit is locked out. Blower and fans are running, however engine wasn't cranking. Technician also found minor coolant leak at pump housing.	Reset and restarted unit	Thought to be caused by electrical power quality
GHP 17	Barstow MCLB	5/22/2007	This unit was displaying lockout behavior starting at 21:09 on 5/22/2007.	Reset and restarted unit	
GHP 17	Barstow MCLB	5/24/2007	A drop in supply voltage caused the unit to lock-out	Installed a device to stabilize the power supply; the unit was reset and restarted unit	
GHP 17	Barstow MCLB	5/28/2007	Refrigerant leak resulting from a broken capillary tube (P125 comp. B)	Repaired broken capillary tube and recharged refrigerant	
GHP 17	Barstow MCLB	6/5/2007	Refrigerant leak resulting from a broken capillary tube on circuit B	Repaired broken capillary tube and recharged refrigerant	
GHP 17	Barstow MCLB	6/25/2007	The TXV for circuit A was stuck in the closed position.	Replaced the TXV, performed a leak check, evacuated the system, and charged with 20lbs. of R407C.	
GHP 17	Barstow MCLB	9/14/2007	Coolant leak at hose clamp on pump	Technician tightened clamp	No down time

Unit	Location	Event Date	U.O.	Repairs	Remarks
GHP 17	Barstow MCLB	9/19/2007	Circuit “A” of the system shut down due to low suction pressure. This was caused by a tripped phase protector, shutting down the blower.	“A” side of the unit was disengaged and compressor “B” was running and providing air-conditioning. Since low suction pressure failures were occurring frequently, the expansion valve was sent to Sporlan for evaluation. Refrigerant oil samples were taken and sent for analysis.	Replaced analog data logger (A1) module and took oil sample from A side for laboratory analysis
GHP 17	Barstow MCLB	10/02/2007	Unit was shutting down from low pressure	Removed oil side A for testing and reprogrammed data logger (TC)	
GHP 17	Barstow MCLB	10/09/2007	Data recorder not recording	Reprogrammed data logger not recording (TC)	
GHP 17	Barstow MCLB	10/24/2007	Unit was shutting down from low pressure	Change out components on circuit A, accumulator, oil separator., TXV, valves, driers etc. (TC)	
GHP 17	Barstow MCLB	11/01/2007	Refrigerant leaking at crimp	Replaced refrigerant hose	
GHP 17	Barstow MCLB	2/26/2008	Broken coolant hose clamp	Replaced hose clamp	
GHP 17	Barstow MCLB	3/13/2008	System running, but tattle tail fuses needed replacement		
GHP 17	Barstow MCLB	3/13/2008	System running, but tattle tail fuses needed replacement		
GHP 17	Barstow MCLB	3/27/2008	System down due to a starter-diode failure	Replaced diodes	
GHP 18	Luke AFB	4/30/2007	The VAV system in the facility closed the supply air dampers	The duct system was set in an operating condition	
GHP 18	Luke AFB	6/26/2007	Shorted wire to refrigerant leak detector caused the unit to shut down	Repaired and restarted unit	

Unit	Location	Event Date	U.O.	Repairs	Remarks
GHP 18	Luke AFB	7/02/2007	LPCO leaking at the wires and lost all refrigerant on Circuit B.	Repaired and recharged refrigerant	
GHP 18	Luke AFB	7/20/2007	Engine failed to start (unknown reason)	Reset and restarted unit	Thought to be power-quality issue
GHP 18	Luke AFB	7/24/2007	TXV malfunction	Replaced TXV and recharged refrigerant	
GHP 18	Luke AFB	12/04/2007	Restriction on 'A' circuit (going into a vacuum).	'A' side unplugged; 'B' side running only.	
GHP 18	Luke AFB	12/21/2007	Unit down due to incorrect installation of a check valve on the 'A' side.	'A' side refrigerant removed. Check valve removed and installed correctly. System vacuumed and recharged with 18lb of refrigerant.	
GHP 18	Luke AFB	12/26/2007	Low pressure on 'B' side. Possible LPCO open.	System reset.	
GHP 18	Luke AFB	1/2/2008		Replaced data card and connected B-Side Compressor	
GHP 18	Luke AFB	1/17/2008	No-heat call from tenant	Analyzed data and replaced refrigerant	
GHP 18	Luke AFB	3/15/2008	High pressure cut out from low indoor air flow	Properly installed new blower belt	
GHP 18	Luke AFB	4/8/2008	LPCO tripped from an improperly installed blower-belt	Properly installed new blower belt	
GHP 19	Nellis AFB	5/4/2007	Refrigerant leak from broken cap tube after vibration absorber	Repaired and recharged refrigerant	
GHP 19	Nellis AFB	5/9/2007	Base power was single-phased, shutting down the indoor blower motor. A coolant leak was also found at the fitting to the pump.	Replaced fuses, installed 3 phase protector, and applied sealant pipe thread at water pump.	
GHP 19	Nellis AFB	6/14/2007	Refrigerant leak detector had tripped causing unit's thermostat to be disabled	Reset the refrigerant leak detector	

Unit	Location	Event Date	U.O.	Repairs	Remarks
GHP 19	Nellis AFB	6/25/2007	Refrigerant leak detector had tripped causing units thermostat to be disabled	Reset the refrigerant leak detector	
GHP 19	Nellis AFB	6/27/2007	Refrigerant leak detector had tripped causing units thermostat to be disabled	Reset the refrigerant leak detector	
GHP 19	Nellis AFB	8/2/2007	Power supply (Sola) had shorted out internally due to heavy rain	Replaced with a new power supply	No down-time
GHP 19	Nellis AFB	10/12/2007	Water pump cracked	Replaced water pump	
GHP 19	Nellis AFB	10/30/2007	Routine maintenance check found a coolant leak under drain pan, oil residue at HPCO, and rust in condensate pan.		
GHP 19	Nellis AFB	11/5/2007	Scheduled replacement of data-logging equipment (the unit operation was not affected).	Change of start counters	
GHP 19	Nellis AFB	11/14/2007	Rusted bearing on blower shaft.	Replaced the bearing.	
GHP 19	Nellis AFB	12/04/2007	Blower motor fuse failed, coolant pump fitting leaking.	Fuse replaced, leak repaired.	
GHP 19	Nellis AFB	12/14/2007	Preventative measure to ensure proper operation in heating mode.	Removed 2 lb of refrigerant.	
GHP 19	Nellis AFB	3/14/08	Unit found not operating from a low pressure cut out	Blower motor failed. This device was replaced on a date later than 3/31	
GHP 20	D-M AFB	4/30/2007	Engine fails to start due to power quality	Reset and restarted unit	
GHP 20	D-M AFB	5/3/2007	Refrigerant leak at solder joint on circuit B at pressure transducer	Evacuated the system, solder leak, and recharged refrigerant	

Unit	Location	Event Date	U.O.	Repairs	Remarks
GHP 20	D-M AFB	5/10/2007	The unit is locked out. Blower and fans are running, however engine wasn't cranking.	Reset and restarted unit	Thought to be caused by a power-quality issue
GHP 20	D-M AFB	5/14/2007	Refrigerant leak resulting from a broken capillary tube (P117 comp. B)	Repaired broken capillary tube and recharged refrigerant	
GHP 20	D-M AFB	5/16/2007	The unit is locked out. Blower and fans are running, however, engine failed to crank.	Reset and restarted unit	Thought to be caused by a power-quality issue
GHP 20	D-M AFB	5/29/2007	Engine no crank (unknown reason)	Reset and restarted unit	Thought to be caused by a power-quality issue
GHP 20	D-M AFB	6/4/2007	Thermostat was programmed at 78° F cooling	Reprogrammed thermostat to customer's desired set point	
GHP 20	D-M AFB	7/23/2007	Engine failed to start resulting from power issues and failed phase protector	Replaced with a new phase protector	
GHP 20	D-M AFB	8/23/2007	Engine will not crank due to the solenoid wire from the starter lose	Tighten wire and restarted unit	
GHP 20	D-M AFB	9/4/2007	System had a frozen indoor coil.	Tightened blower belt, defrosted system	Caused by improper belt tension and inadequate ducting
GHP 20	D-M AFB	9/13/2007	Found failed phase monitor.	Replaced phase monitor	
GHP 20	D-M AFB	9/17/2007	Frozen coil, side 'B' low on charge. No leaks were apparent.	Added 2 lb of R407C, Reset and restarted unit	Caused by poor indoor airflow conditions
GHP 20	D-M AFB	10/2/2007	Frozen indoor coil		Caused by poor indoor airflow conditions
GHP 20	D-M AFB	10/4/2007	Frozen indoor coil		Caused by poor indoor air-flow conditions
GHP 20	D-M AFB	10/9/2007	Circuit A tattle tale fuse open LPCO	Unit reset	Caused by a TXV issue

Unit	Location	Event Date	U.O.	Repairs	Remarks
GHP 20	D-M AFB	10/29/2007	System down on a fault		Unknown Reason
GHP 20	D-M AFB	12/06/2007	Circuit protector failed.	Repaired.	
GHP 20	D-M AFB	12/06/2007	HPCO in heating mode	reset	Caused by poor indoor air-flow from ductwork
GHP 20	D-M AFB	12/17/2007	System shuts down on high head in heating.	Removed of 2 lb of refrigerant.	
GHP 20	D-M AFB	2/5/2008	Reason for shutdown is unknown. At this time it is suspected to be an electrical power issue.	Unit was reset	
GHP 21	Yuma MCAS	5/21/2007	Refrigerant leak	Repaired and recharged refrigerant	
GHP 21	Yuma MCAS	5/23/2007	Natural gas leak	Repaired	
GHP 21	Yuma MCAS	6/18/2007	Loose relay	Repaired	
GHP 21	Yuma MCAS	6/21/2007	Refrigerant quantity/mixture	Repaired	
GHP 21	Yuma MCAS	6/25/2007	Refrigerant quantity/mixture , the refrigerant be recovered from both sides	Recharged 20 lb of refrigerant to each side	
GHP 21	Yuma MCAS	6/26/2007	Refrigerant quantity/mixture	Repaired	
GHP 21	Yuma MCAS	6/27/2007	Shorted wire to refrigerant leak detector	Repaired	
GHP 21	Yuma MCAS	7/3/2007	False Refrigerant leak detector had tripped causing units thermostat to be disabled	Reset the refrigerant leak detector	
GHP 21	Yuma MCAS	7/6/2007	Engine failed to start (unknown reason)	Reset and restarted unit	Possible power issue
GHP 21	Yuma MCAS	7/12/2007	Engine failed to start (unknown reason)	Reset and restarted unit	False refrigerant alarm
GHP 21	Yuma MCAS	7/15/2007	Indoor blower fuse blown	Repaired	

Unit	Location	Event Date	U.O.	Repairs	Remarks
GHP 21	Yuma MCAS	7/20/2007	Engine failed to start (unknown reason)	Reset and restarted unit	False refrigerant alarm
GHP 21	Yuma MCAS	7/25/2007	Unit down due to the refrigerant detector	Reset and restarted unit	False refrigerant alarm
GHP 21	Yuma MCAS	7/26/2007	Engine failed to start (unknown reason)	Reset and restarted unit	False refrigerant alarm
GHP 21	Yuma MCAS	8/2/2007	Unit locked-out on a fault	Reset and restarted unit	False refrigerant alarm
GHP 21	Yuma MCAS	8/3/2007	Low pressure cut-out due to malfunctioning TXV	Repaired and recharged refrigerant	
GHP 21	Yuma MCAS	8/9/2007	Engine failed to start (unknown reason)	Reset and restarted unit	Possible power quality issue
GHP 21	Yuma MCAS	8/19/2007	Unit went down due to excessive head pressure on the 'B' side coil	Reset manual HPCO, check out some components. fans, pressures etc. and restarted unit	
GHP 21	Yuma MCAS	8/28/2007	System down due to a wire being cut off inside a butt connector	Repaired the wires and restarted unit	
GHP 21	Yuma MCAS	8/29/2007	Head pressure connectors came loose causing a false safety shut down	Repaired the wire, reset the system	
GHP 21	Yuma MCAS	9/6/2007	System down due to faulty HPCO on side "A" being open	Reset switch, reset unit, washed coils	
GHP 21	Yuma MCAS	9/17/2007	System down due to faulty HPCO on side "A" being open	System reset and operating. New automatic reset HPCO switches were shipped to be installed	
GHP 21	Yuma MCAS	12/14/2007	Preventative measure to ensure proper operation in heating mode.	Removed 2 lb of refrigerant.	
GHP 21	Yuma MCAS	12/19/2007	Gas leak detected on main line coupling going to the unit from the meter on rooftop.	Leak eliminated.	

Unit	Location	Event Date	U.O.	Repairs	Remarks
GHP 22	Fort Huachuca AG	5/1/2007	Unit in heat mode created a smell and customer turned off the unit	No indication of any failure	
GHP 22	Fort Huachuca AG	7/6/2007	Unit locked out on a fault	Reset and restarted unit	Possible power quality issue
GHP 22	Fort Huachuca AG	7/24/2007	Attic air is mixing with indoor air	N/A	Major ductwork overhaul must be performed
GHP 22	Fort Huachuca AG	8/6/2007	Unit down due to ductwork improperly installed	Tempco checked ductwork and restarted unit	
GHP 22	Fort Huachuca AG	8/11/2007	Unit down due to ductwork	Tempco restarted unit	
GHP 22	Fort Huachuca AG	8/26/2007	Unit down due to ductwork	Tempco restarted unit	
GHP 22	Fort Huachuca AG	8/29/2007	There was a short on the starter relay, which inhibited the starter from energizing.	Replaced wires in terminals 8 and 5 and restarted unit	
GHP 22	Fort Huachuca AG	9/1/2007	Low pressure cut-out open, possible frozen coil, air balance, TXV	Checking all components	Most-likely caused by part-load TXV issues
GHP 22	Fort Huachuca AG	9/13/2007	Checked air balance, reprogramming of data logger , added tattle tales, changed sheave and belts	Reset and restarted unit	
GHP 22	Fort Huachuca AG	9/14/2007	Circuit "A" of the system shut down due to low suction pressure.	"A" side of the unit pulled and compressor "B" is running and providing air-conditioning. Expansion valve and filter driers will be replaced	
GHP 22	Fort Huachuca AG	9/18/2007	The TXV malfunction	Replaced HPCO	Replaced TXV
GHP 22	Fort Huachuca AG	9/19/2007	Unit found down in lock-out†		
GHP 22	Fort Huachuca AG	10/10/2007	Diode failed, a starter failure, caused by a faulty gas-valve wiring.	Replaced failed and improper wiring	

Unit	Location	Event Date	U.O.	Repairs	Remarks
GHP 22	Fort Huachuca AG	12/13/2007	Outdoor coil froze in heating mode due to improperly set defrost controls		
GHP 22	Fort Huachuca AG	1/2/2008	System down from high-pressure cut out. After examining data, engineering concluded that a problem was occurring in the indoor compartment. The blower motor shut down from over heating, caused by excessive belt tension.	After adjusting belt tension, the unit has been running normally.	
GHP 22	Fort Huachuca AG	2/1/2008	Replacement of Ductwork		
GHP 22	Fort Huachuca AG	2/8/2008	Unknown shutdown possibly due to base's poor electrical power quality	Reset unit	
GHP 22	Fort Huachuca AG	2/13/2008	Shutdown caused by the refrigerant alarm, which was supposed to be removed in September	The alarm was removed and the unit was reset.	Prior unknown shutdowns for GHP 22 could have been caused by this remaining refrigerant sensor.

3.5.2 Combined economic results

Accounting for all operating hours in the field test, Table 8 gives an economic summary and comparison.

Table 8. Summary and comparison of total operating costs and savings.

Unit	Natural Gas	Power	Total
Barstow MCLB	$3,949	$2,212	$6,162
Luke AFB	$1,663	$1,256	$2,919
Nellis AFB	$964	$466	$1,430
Davis-Monthan AFB	$2,477	$1,349	$3,826
Yuma MCAS	$1,896	$808	$2,705
Fort Huachuca AG	$3,344	$2,311	$5,656

EHP total operating cost			
Unit	Natural Gas	Power	Total
Barstow MCLB	$0	$8,256	$8,256
Luke AFB	$0	$5,053	$5,053
Nellis AFB	$0	$2,110	$2,110
Davis-Monthan AFB	$0	$5,116	$5,116
Yuma MCAS	$0	$3,959	$3,959
Fort Huachuca AG	$0	$7,612	$7,612

GHP total operating cost savings, compared to EHP*		
Unit	Difference in Operating Cost ($)	Operating Cost Savings (%)
Barstow MCLB	$2,094	25%
Luke AFB	$2,134	42%
Nellis AFB	$680	32%
Davis-Monthan AFB	$1,289	25%
Yuma MCAS	$1,254	32%
Fort Huachuca AG	$1,957	26%

*The savings was calculated only on the heating therms consumed.

As seen in the preceding table, there were significant economical savings at the Barstow MCLB, Luke AFB, Yuma MCAS, and Fort Huachuca installations. Nellis AFB lacked significant savings because of extremely short times of operation. Additionally, Nellis AFB primarily ran in cooling mode (presumably due to kitchen operations), even in the winter months.

4 Discussion and Conclusion

4.1 Lessons from field demonstration

From the installation, operation, and testing of the six Model 5 GHPs, the following lessons were learned.

4.1.1 Mechanical performance

Within a few weeks of implementation, refrigerant leaks occurred. It was determined that the use of capillary tubes to connect pressure transducers for data logging and safety switches subsequently vibrated excessively, cracking the refrigerant line. From these occurrences, it was learned that using a small rigid copper line, combined with a refrigerant hose, reduced the excessive vibration and eliminated the leaks.

After the units lost refrigerant, it was decided to use refrigerant sensors to help alert anyone to the potential presence of oxygen-displacing refrigerant, in the event of catastrophic refrigerant leaks. After these highly-sensitive devices were installed, they routinely shut down the units on false alarms caused by janitorial cleaning compounds, jet fumes, and food particles. It was learned that these sensing devices should only be used when the risk of major refrigerant leaks is extremely high.

Several low-suction pressure shutdowns occurred due to the clogging of thermal expansion valves. A few seconds after start-up, the system suction pressure would go below 10 psi. These failures started to occur right after Phase I, II, and III upgrades. During those upgrades, the system was open at several locations to remedy the excessive vibration and breakage of the data-logging capillary tubes. Unfortunately, at the time of these phase upgrades, proper procedures were not followed to prevent system contamination. Some causes that led to these failures include: brazing without purging the lines with nitrogen, inadequate system evacuation, and not replacing liquid line filter driers after opening the system.

Another contributing factor to the clogging problem is that Polyolester (POE) oils are more hygroscopic than mineral oils (meaning they absorb more free water as well as moisture from the atmosphere). The sample oil test taken form the units showed high levels of moisture. The POE will collect much of the contaminants in the system and precipitate them in the expansion device, eventually leading to plugging/sticking. Several hours were dedicated to identifying and documenting the root cause of the failures. Based on the analysis, design changes will be incorporated in the next GHP model, including a new filter drier specification and a new oil management design. Additionally, it will be assured that all future field repairs and maintenance tests will be performed carefully and correctly.

Since the beginning of these field tests, two of the units were installed with pre-existing faulty ductwork. Knowing that heat pumps are highly sensitive to the ventilation configuration, engineering personnel should inspect every site prior to installation, to assure proper ductwork is in place.

The flow meters that measured the refrigerant mass flow rate and fuel consumption proved unreliable during the field test. It was decided to use SWG's positive-displacement gas meters and hour counters to achieve seasonal fuel consumption, while airside measurements were used for determining capacity. Although these meters are not used for billing, the pressure leading to the units should be a 7 in. water column. It was noticed that the Davis-Monthan AFB installation had incorrect pressure readings at the meter, limiting the ability to obtain seasonal efficiency information.

4.1.2 Electrical performance

The electrical system on the GHP was designed with a starter transformer that converted 240 VAC to 16 VAC. The units were expected to be installed with 208 VAC, producing 13.92 VAC for the starter at all locations except Fort Huachuca AG which had 240 VAC. Tests for 208V starts were conducted at Team Consulting to assure a starting voltage of 208 would suffice. All tests proved to be successful. Once the units were installed in the field, many failed to start. These outages resulted from the bases having poor power quality with supply voltages of 190V and below. Once this issue was identified, 208V to 240C buck-and-boost transformers were installed. These devices assured a constant supply voltage to the unit.

An additional electrical problem experienced by the GHPs concerned three-phase power. Occasionally, a leg of the three-phase power would drop, causing the indoor blower motor to overheat. Because the indoor blower motor was the only three-phase component, this did not cause problems with the rest of the electrical system. Since this type of power problem is relatively common, phase protectors were installed on the units. These would immediately shut down the unit in the event of loosing a leg of the three-phase power, protecting the blower motor.

4.1.3 Data acquisition

The cellular or e-mail transmission of data early in testing proved to be highly unreliable. The majority of the GHPs suffered greatly from this hindrance. To gain a more reliable method of obtaining readings, flash memory cards were used and data was physically mailed data to the consulting team for analysis. In future tests, a cellular router with a static Internet Protocol (IP) will be used in conjunction with a reliable storage back-up to assure a robust system of data transmission.

As observed at the Barstow installation, the National Instrument's compact field point modules proved to be extremely sensitive to moisture. To help prevent this destruction, future tests will use weather-tight enclosures placed within the indoor section of the GHP.

When running the software macro that created the monthly summaries, debug warnings and errors would occur from instances when the unit would reset. This is because cells or entire rows of data would be shifted to the left. Each time, before the program could be run, all files had to be searched for these anomalies, consuming large amounts of time. Future tests will include a more robust data acquisition program that will clean the data prior to running summarization programs.

When the field test came to an end, it was noticed that many of the physical test points on the units were never used. To help save memory and ease readability of data, in future tests great care will be taken to reduce the number of thermocouples and pressure transducers.

As discussed in the development portion of the report, the natural gas and refrigerant flow meters failed to read accurately during the majority of the field tests. It was learned that the flow meters can be easily disregarded without affecting the accuracy of the field tests. It was also learned that laboratory instruments proved too sensitive for field test use.

4.2 Concluding remarks

This report summarized operational results from the six units of Model 5 GHP systems, as demonstrated at six DoD installations in the Southwest region of the United States. Extensive data on GHP system operation, system reliability, and energy performance were documented. The Model 5 is a beta-version product ready for commercialization, with final improvement based on the test results reported from this field demonstration.

The objectives of field demonstration were: (1) to verify technical feasibility of GHP technology for space heating and cooling applications, (2) to gain field operation experience from the beta version of GHP systems for final product development, and (3) to analyze energy and economic performance of GHP systems during a 1-year field demonstration. These objectives were successfully accomplished. During the 1-year field testing (April 2007 to March 2008) at six DoD installations, the units produced an average unit COP of 1.38 in the heating season and 1.25 in the cooling season.

Based on the measured energy efficiencies, annual energy cost savings for heating and cooling were calculated to be between $680 and $2,134 at each site, compared to high-efficiency EHPs. In addition, 261,473 gallons of fresh water is estimated to be saved at the power plants, due to reduced consumption of electricity compared to use of electric heat pumps. As stated earlier, the estimate is based on 2 gallons of fresh water consumed per each kilowatt-hour of electricity generation, as reported for U.S. power production.

Lessons learned from this field demonstration of the Model 5 units will be applied to the commercialization of GHP technology (as the “Model 6”). Demonstration of the commercial version of GHP systems (Model 6) is in progress at five DoD installations for a 1-year period beginning in March 2009.

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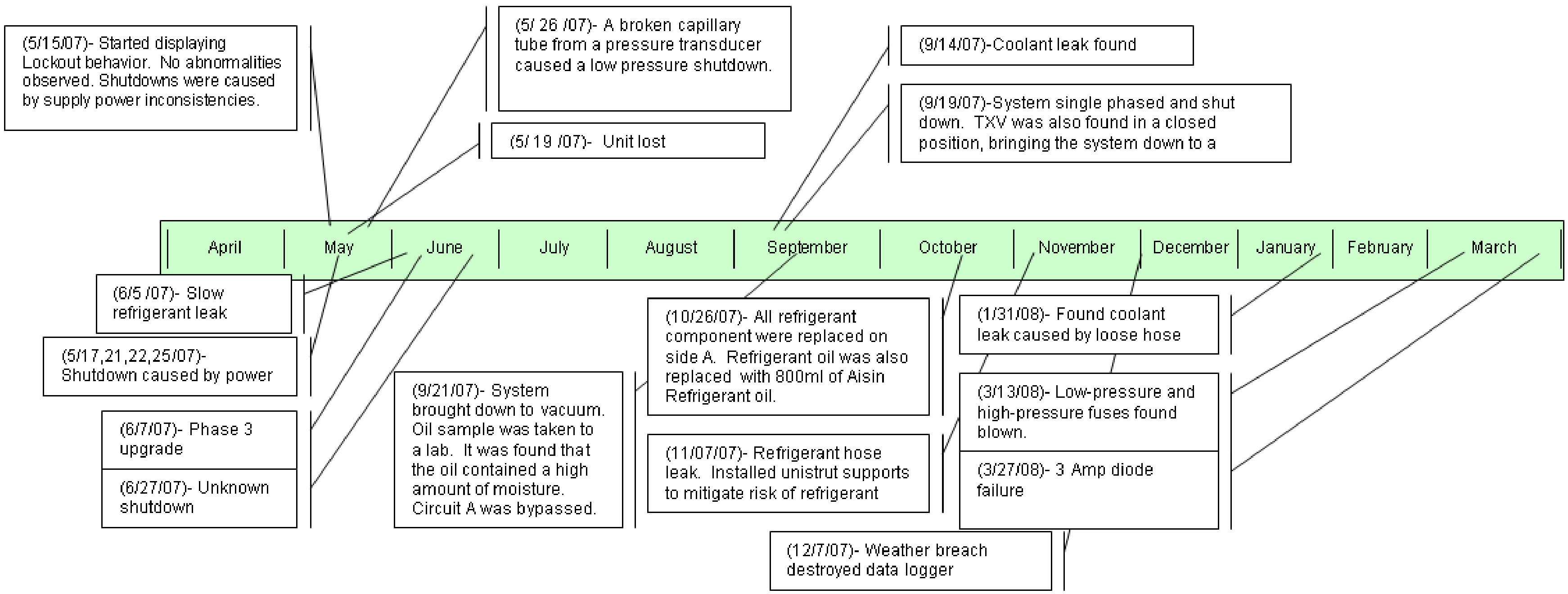
Acronyms and Abbreviations

Term	Spellout
AFB	Air Force Base
AG	Army Garrison
ANSI	American National Standards Institute
APS	Arizona Public Service Co.
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BAA	Broad Agency Announcement
BME	Blue Mountain Energy
BTU	British thermal unit
CAD	computer-aided design
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Ctr.
CERL	Construction Engineering Research Laboratory
CF	Facilities Division of CERL
CF-E	Facilities Division, Energy Branch of CERL
CFR	Code of Federal Regulations
COP	coefficient of performance
DoD	Department of Defense
DX	direct expansion
EHP	electric heat pump
ERDC	Engineer Research and Development Center
GEDAC	gas engine drive air-conditioner
GHP	gas engine driven heat pump
GPO	Government Printing Office
GS	general service
HPCO	high pressure cut-out
IP	internet protocol
LGS	large general service
LPCO	low pressure cut-out
MCAS	Marine Corps Air Station
MCLB	Marine Corps Logistics Base
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
ODDR&E	Office of the Director, Defense Research & Engineering
PE	program element
POE	polyolester

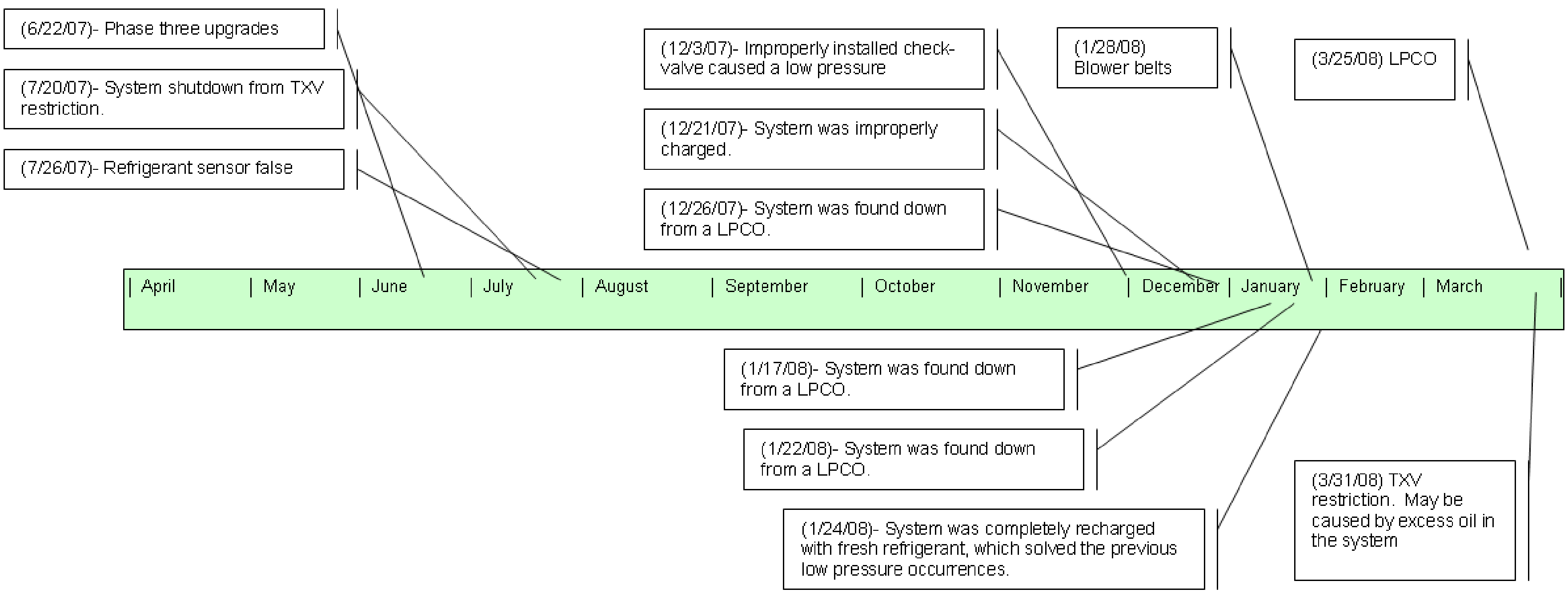
Term	Spellout
RH	relative humidity
RPM	revolutions per minute
RT	refrigerant ton
SCE	Southern California Edison
SI	Systeme Internationale
TC	Technical Committee
TR	technical report
TXV	thermostatic expansion value
UO	unscheduled outage
URL	universal resource locator
VAC	volt AC
VAV	variable air volume
VRV	variable refrigerant volume
WWW	World Wide Web

Appendix A: Timeline of events for the six GHP installations

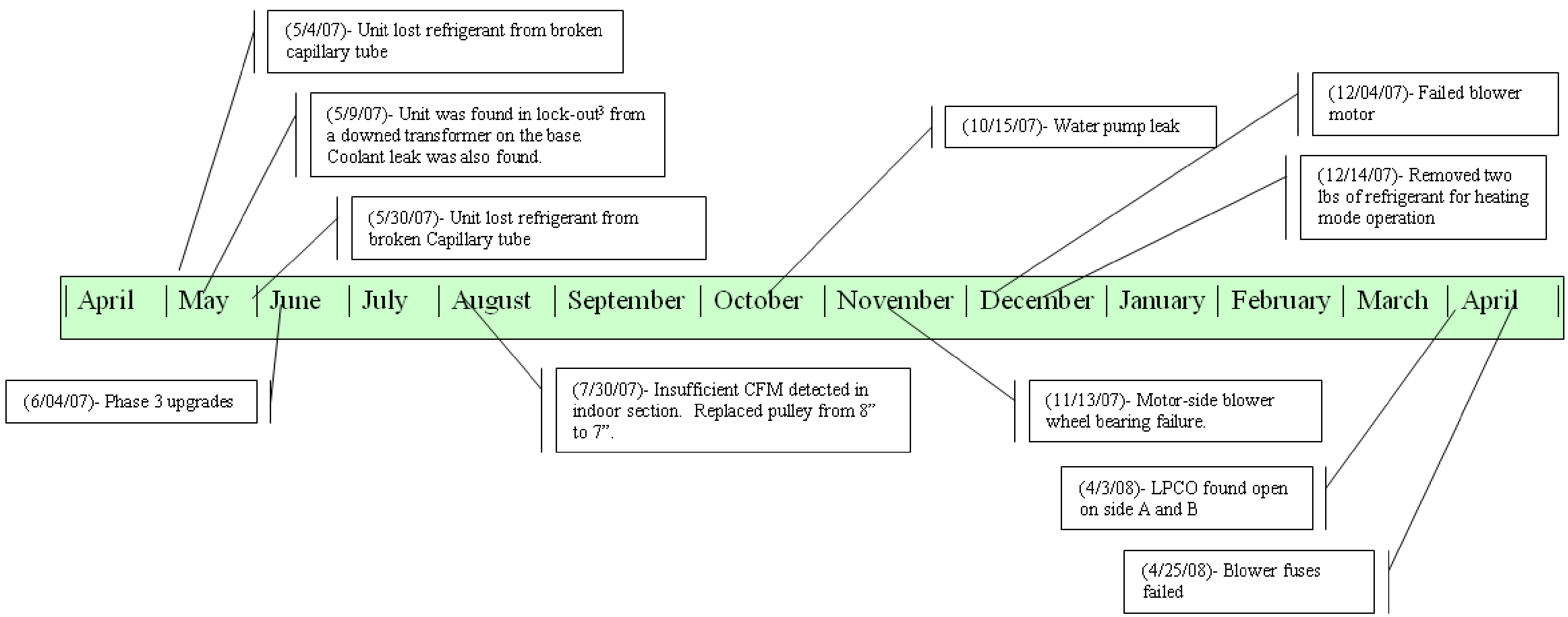
GHP 17 Timeline



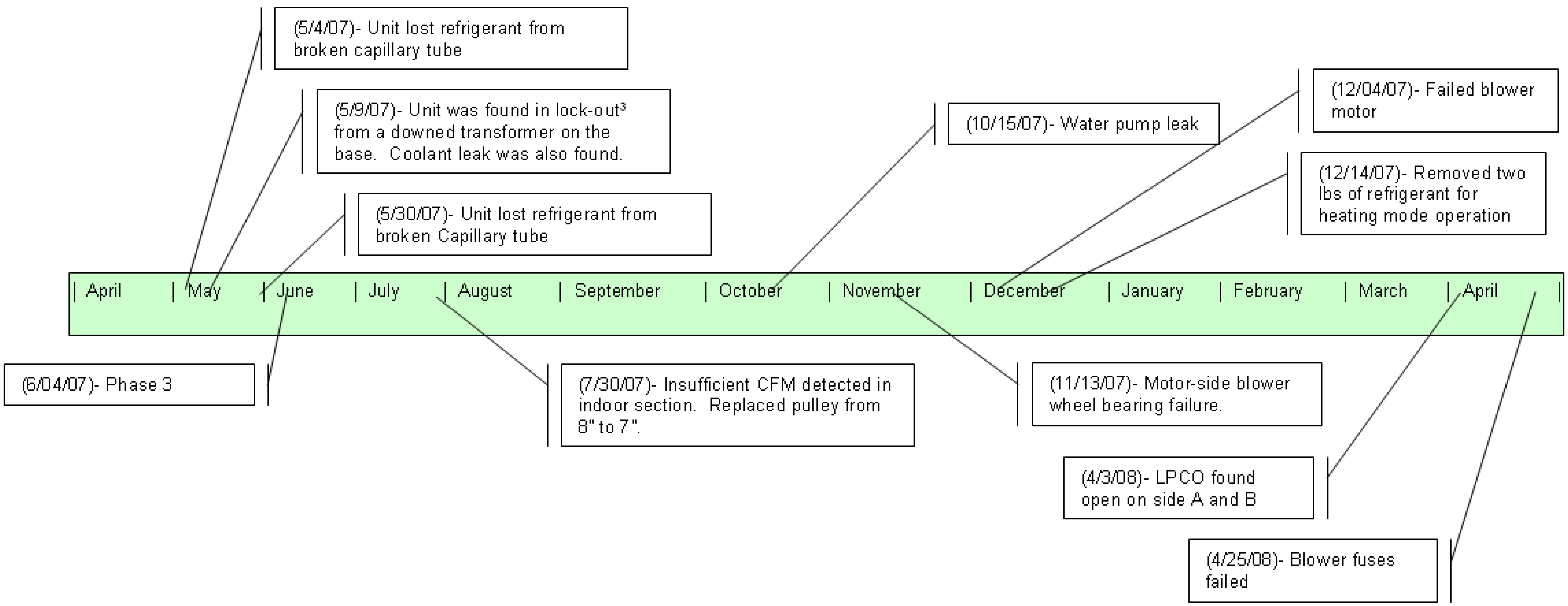
GHP 18 Timeline



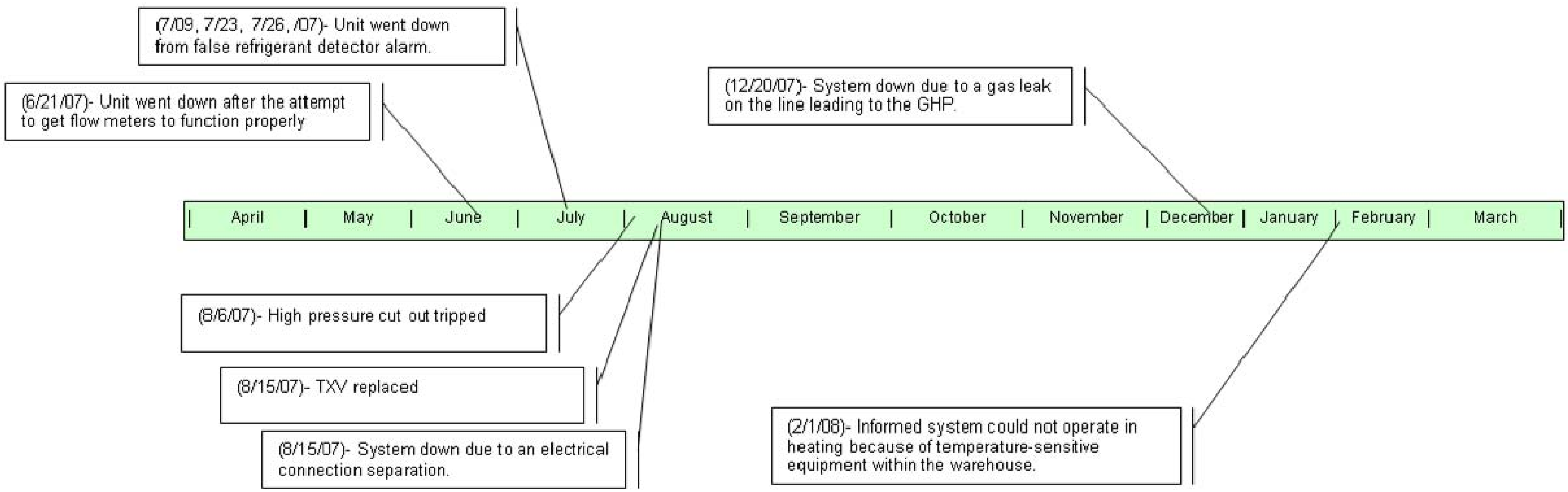
GHP 19 Timeline



GHP 20 Timeline



GHP 21 Timeline



Appendix B: GHP 17 Performance Data

Unit:	GHP 17
Site	Barstow MCLB
Analysis Period:	July 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
06/30/07	3.78	231053.15	2484.85	61071.32	82273.81	1.33	1.17	89.14
07/01/07	22.48	1716682.16	2669.33	76353.54	95698.68	1.32	1.16	94.87
07/02/07	12.93	887626.86	2603.57	68630.94	92673.89	1.42	1.24	89.84
07/05/07	7.20	717527.00	2975.51	99656.53	115791.68	1.17	1.06	107.06
07/06/07	23.75	2080698.61	2763.79	87608.36	104962.67	1.23	1.10	103.21
07/07/07	22.88	1912823.49	2755.65	83590.25	102112.10	1.26	1.13	98.85
07/08/07	22.72	1740904.47	2671.46	76635.56	96042.19	1.30	1.15	94.71
07/09/07	23.18	1805326.41	2707.31	77871.74	100588.01	1.35	1.19	94.50
07/10/07	22.08	1404192.55	2580.43	63586.08	92019.69	1.44	1.26	88.53
07/11/07	22.33	1586143.50	2664.60	71021.35	99000.59	1.46	1.28	89.31
07/12/07	22.15	1607195.50	2681.12	72559.62	97774.85	1.42	1.24	89.94
07/13/07	22.87	1751965.61	2700.28	76616.57	98737.93	1.36	1.20	93.43
07/14/07	22.73	1810147.78	2721.96	79625.27	100790.55	1.30	1.16	96.42
07/15/07	22.75	1842833.95	2736.63	81003.69	102467.27	1.29	1.15	97.58
07/16/07	22.78	1871121.70	2779.36	82126.78	107883.71	1.35	1.20	95.56
07/17/07	23.00	1806531.53	2731.37	78544.85	102679.54	1.36	1.20	94.10
07/18/07	22.95	1732110.63	2685.84	75473.23	99534.50	1.39	1.22	92.39
07/19/07	23.03	1697268.86	2675.37	73687.50	100694.71	1.44	1.26	90.41
07/20/07	20.82	1347739.95	2423.30	64743.31	86631.95	1.40	1.23	89.91
07/21/07	13.48	830948.25	1758.07	61627.81	75489.70	1.23	1.10	90.16
07/22/07	17.12	997938.42	2105.25	58302.15	72901.99	1.28	1.13	92.89
07/23/07	10.98	680338.18	2079.11	61942.78	80258.39	1.29	1.16	95.19

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 17							
Site	Barstow MCLB							
Analysis Period:	August 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
07/31/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	91.07
08/01/07	16.88	938063.73	2028.50	55561.52	80019.29	1.44	1.28	89.93
08/02/07	16.13	957536.88	1966.02	59351.46	80177.69	1.35	1.21	93.47
08/03/07	16.27	984149.78	2025.94	60501.01	78532.78	1.30	1.16	94.95
08/04/07	16.70	998661.19	2026.78	59800.07	74316.25	1.24	1.11	96.59
08/05/07	16.60	959859.96	2038.96	57822.89	74939.78	1.30	1.16	92.29
08/06/07	15.80	855103.75	1991.97	54120.49	78026.34	1.44	1.28	85.37
08/07/07	14.43	808290.31	1868.48	56001.64	77438.09	1.38	1.24	84.15
08/08/07	14.90	841347.92	1919.51	56466.30	82097.28	1.45	1.30	85.15
08/09/07	14.78	846395.95	1894.06	57253.39	79129.49	1.38	1.24	86.12
08/10/07	14.95	863483.07	1905.28	57758.06	78160.28	1.35	1.22	87.32
08/11/07	14.37	849817.99	1819.78	59152.06	78214.47	1.32	1.20	89.17
08/12/07	14.57	868148.47	1832.43	59598.29	76237.11	1.28	1.16	91.29
08/13/07	16.73	1002559.06	2051.40	59913.89	79023.36	1.32	1.18	94.44
08/14/07	14.33	825642.38	2139.58	57602.96	82559.21	1.43	1.27	91.89
08/15/07	8.00	586262.59	2516.69	73282.82	101059.32	1.38	1.23	103.11
08/16/07	17.57	1106415.26	2190.34	62983.79	87890.66	1.40	1.25	95.33
08/17/07	17.35	1094179.08	2237.39	63065.08	89771.48	1.42	1.27	93.39
08/18/07	18.07	1081510.50	2173.24	59862.20	82416.15	1.38	1.23	93.80
08/19/07	16.55	966957.63	2033.51	58426.44	77367.46	1.32	1.18	91.10
08/20/07	16.40	966800.32	2083.05	58951.24	78045.90	1.32	1.18	90.32
08/21/07	16.48	969515.80	2081.55	58817.95	77142.45	1.31	1.17	90.98
08/22/07	17.12	1053597.96	2211.81	61553.92	85163.68	1.38	1.23	92.34
08/23/07	17.93	1097098.83	2241.01	61176.51	86084.71	1.41	1.25	93.38
08/24/07	16.20	990400.54	2112.70	61135.84	85735.09	1.40	1.25	90.98
08/25/07	16.97	1038579.03	2144.36	61212.91	86786.91	1.42	1.27	92.80
08/26/07	18.02	1055490.53	2149.48	58584.12	83591.51	1.43	1.27	92.52
08/27/07	16.57	1037584.18	2210.15	62630.84	89914.04	1.44	1.28	91.44
08/28/07	17.90	1118770.47	2270.33	62501.14	89483.89	1.43	1.27	94.18
08/29/07	18.25	1174534.62	2311.27	64358.06	91572.62	1.42	1.27	96.64
08/30/07	5.28	296023.30	2043.53	56029.65	80848.91	1.44	1.28	92.53
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

Unit:	GHP 17							
Site	Barstow MCLB							
Analysis Period:	September 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
08/31/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	89.44
09/01/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	96.55
09/02/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	97.56
09/03/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	95.21
09/04/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	94.31
09/05/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	86.04
09/06/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	84.46
09/07/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	83.55
09/08/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	85.50
09/09/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	85.87
09/10/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	84.77
09/11/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	85.48
09/12/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	85.17
09/13/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	86.32
09/14/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	78.71
09/15/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	77.47
09/16/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	76.94
09/17/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	75.97
09/18/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	77.68
09/19/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	72.96
09/20/07	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	57.41
09/25/07	3.10	156730.90	1910.25	50558.35	93602.14	1.85	1.64	86.25
09/26/07	10.78	532975.58	1448.56	49425.87	96009.87	1.94	1.77	72.65
09/27/07	10.08	514274.19	1376.19	51002.40	94335.06	1.85	1.69	74.55
09/28/07	11.63	582813.51	1529.30	50098.58	107772.21	2.15	1.95	76.00
09/29/07	4.55	174688.42	1287.91	38393.06	113653.28	2.96	2.66	62.36
09/30/07	10.98	483864.33	2347.32	44054.42	69698.13	1.58	1.34	64.18

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 17							
Site	Barstow MCLB							
Analysis Period:	October 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
10/01/07	11.28	584705.57	1497.55	51820.29	90198.75	0.72	0.65	75.25
10/02/07	4.55	217571.47	1274.10	47817.91	110389.16	0.79	0.72	66.15
10/09/07	1.85	85100.00	2145.50	46000.00	98741.42	0.81	0.70	68.56
10/10/07	8.82	429065.66	1265.10	48665.29	88864.77	0.76	0.70	72.52
10/11/07	14.38	651009.17	1862.33	46667.32	95605.88	0.77	0.67	66.97
10/12/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	69.72
10/13/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	72.09
10/14/07	8.48	407011.36	1224.12	47977.76	102729.33	0.77	0.71	72.88
10/15/07	16.98	762495.39	2175.79	48825.75	89595.42	0.71	0.62	70.15
10/16/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	65.50
10/17/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	65.94
10/18/07	17.08	694845.03	2238.60	46323.00	86992.56	0.73	0.63	65.15
10/19/07	17.02	748084.31	2204.21	49651.61	91599.76	0.70	0.61	71.14
10/20/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	68.77
10/21/07	17.27	580866.78	2394.89	46039.64	50484.13	0.66	0.56	62.10
10/22/07	17.40	588800.00	2418.96	46000.00	60963.26	0.72	0.61	61.05
10/23/07	17.23	662307.30	2327.53	48580.00	71926.77	0.70	0.60	66.91
10/24/07	10.30	370697.47	2271.72	47423.98	70708.23	0.69	0.59	67.25
10/25/07	14.08	749093.44	2458.88	65709.95	129456.78	0.92	0.82	70.11
10/26/07	16.83	1071133.46	3102.19	82289.38	163966.52	0.99	0.88	70.17
10/27/07	16.18	925124.95	3056.44	78845.88	134542.92	0.96	0.85	68.15
10/28/07	0.00	0.00	1377.44	F.O.	F.O.	F.O.	F.O.	75.39
10/29/07	4.82	360343.33	1872.90	82521.37	228818.11	1.09	1.01	70.82
10/30/07	13.42	930546.40	2755.61	81626.88	197432.00	0.97	0.87	69.31
10/31/07	15.17	892822.04	3120.55	80798.37	156590.23	0.95	0.84	68.34

Note: F.O. stands for the unit was operable but the tenant was running the fans only.

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 17
Site:	Barstow MCLB
Analysis Period:	November 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
10/02/07	4.82	263826.09	2301.23	55737.91	108629.84	1.95	1.71	91.30
10/03/07	2.38	119661.24	2057.80	50207.51	105268.91	2.10	1.84	84.80
10/31/07	1.67	86236.82	3144.05	74988.54	133686.03	1.78	1.56	62.19
11/01/07	16.62	964066.15	3130.84	80900.66	154108.66	1.90	1.68	67.51
11/02/07	17.15	1022325.01	3124.80	80922.82	154870.21	1.91	1.69	67.45
11/03/07	17.22	935103.81	3145.45	80961.37	127012.45	1.57	1.39	65.62
11/04/07	17.30	883832.36	3144.64	79149.17	110949.58	1.40	1.23	64.39
11/05/07	16.93	1010485.51	3108.58	81600.45	143536.07	1.76	1.56	69.03
11/06/07	17.05	1051382.33	3112.46	82353.71	153391.93	1.86	1.65	69.56
11/07/07	16.80	1085274.10	3100.95	83375.73	161485.25	1.94	1.72	71.70
11/08/07	16.82	1027034.64	3108.77	81188.51	162337.49	2.00	1.77	68.66
11/09/07	16.92	954046.82	3109.46	77987.48	149145.45	1.91	1.68	64.19
11/10/07	17.15	870707.70	3131.14	76827.15	122346.84	1.59	1.40	61.23
11/11/07	17.35	873800.31	3121.29	77671.14	132066.29	1.70	1.50	61.87
11/12/07	16.92	902399.45	3120.82	78469.52	138297.78	1.76	1.55	65.13
11/13/07	17.23	918948.46	3110.15	78879.70	142365.40	1.80	1.59	63.52
11/14/07	16.92	932106.71	3105.64	80009.16	151109.60	1.89	1.67	65.67
11/15/07	17.18	966191.94	3097.75	79850.57	145795.77	1.83	1.61	65.77
11/16/07	16.13	898899.19	3111.08	80139.60	153882.72	1.92	1.70	65.93
11/17/07	17.18	918653.05	3092.44	79080.61	132234.00	1.67	1.48	64.44
11/18/07	17.22	892160.98	3102.41	79303.20	127632.83	1.61	1.42	63.70
11/19/07	17.30	976428.89	3189.17	81256.22	139002.76	1.71	1.51	66.48
11/20/07	16.93	975316.35	3229.26	79294.01	145556.41	1.84	1.61	65.97
11/21/07	17.37	751472.65	3277.77	75147.26	77987.55	1.04	0.90	54.93
11/22/07	17.82	606441.04	3287.11	75023.63	53984.29	0.72	0.63	50.03
11/23/07	17.62	598754.98	3289.86	75000.62	58481.53	0.78	0.68	49.19
11/24/07	17.63	654436.79	3278.88	75511.94	70655.16	0.94	0.81	53.46
11/25/07	17.65	623754.88	3285.37	75000.59	59474.66	0.79	0.69	49.57
11/26/07	17.62	718936.89	3278.04	75412.96	74710.81	0.99	0.86	53.69
11/27/07	17.72	732859.63	3275.65	75165.09	88640.29	1.18	1.03	52.78
11/28/07	13.28	377637.99	3312.61	74289.44	78973.00	1.06	0.92	51.35
11/29/07	14.38	13800.00	3289.80	46000.00	8753.97	0.19	0.15	49.74
11/30/07	6.32	0.00	3224.27	F.O*	F.O.	F.O.		44.31

Note: F.O. stands for the unit was operable but the tenant was running the fans only.

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Appendix C: GHP 18 Performance Data

Unit:	GHP 18
Site	Luke AFB
Analysis Period:	July 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
06/30/07	2.37	142221.26	1120.71	60093.49	64799.16	1.08	0.96	97.91
07/01/07	16.67	1004547.81	1563.42	60272.87	67062.29	1.14	1.00	98.13
07/02/07	1.92	103621.84	2054.44	54063.57	68035.74	1.26	1.11	87.66
07/03/07	9.70	672467.88	2022.45	69326.59	72454.70	1.05	0.94	105.50
07/04/07	14.72	892362.98	1487.66	60636.22	72370.39	1.21	1.08	100.64
07/05/07	16.65	1018919.67	1689.28	61196.38	73816.41	1.22	1.08	100.76
07/06/07	14.95	915330.48	1549.19	61226.12	76027.10	1.25	1.11	101.42
07/07/07	12.22	739043.06	1219.29	60494.66	79361.74	1.33	1.18	100.48
07/08/07	10.77	647540.71	1096.94	60143.10	80689.90	1.36	1.21	99.09
07/09/07	11.03	665228.59	1205.33	60292.62	78657.82	1.32	1.17	97.20
07/10/07	13.42	782752.74	1345.45	58341.82	75836.12	1.31	1.16	95.27
07/11/07	12.37	739301.84	1399.87	59781.82	75833.40	1.28	1.14	97.64
07/12/07	13.58	825994.16	1358.14	60809.39	75276.39	1.25	1.11	99.13
07/13/07	12.12	720643.08	1236.41	59475.36	77370.71	1.32	1.17	97.34
07/14/07	10.42	621937.56	1060.51	59706.01	79900.91	1.36	1.20	98.35
07/15/07	11.40	692180.48	1110.45	60717.59	81052.60	1.35	1.20	100.32
07/16/07	12.78	781368.80	1333.94	61124.03	81481.58	1.35	1.20	99.68
07/17/07	15.90	959161.15	1594.34	60324.60	80827.63	1.35	1.20	99.44
07/18/07	13.75	849545.11	1461.65	61785.10	78749.59	1.28	1.15	102.71
07/19/07	8.20	565569.94	2184.71	68971.94	88543.82	1.29	1.15	99.75
07/20/07	5.18	332283.76	2596.74	64106.19	91651.78	1.45	1.27	93.81
07/21/07	0.00	0.00	3118.87	U.O.	U.O.	U.O.	U.O.	92.81
07/22/07	0.00	0.00	3119.20	U.O.	U.O.	U.O.	U.O.	90.61
07/23/07	0.00	0.00	3109.57	U.O.	U.O.	U.O.	U.O.	90.61
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

Unit:	GHP 18
Site	Luke AFB
Analysis Period:	August 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
07/31/07	4.50	266958.75	2120.97	59324.17	92541.73	1.56	1.39	99.03
08/01/07	12.47	677421.75	1243.19	54338.64	94664.93	1.74	1.62	87.83
08/02/07	10.93	579879.06	1185.53	53037.72	94793.89	1.79	1.66	86.39
08/03/07	12.55	731187.52	1241.02	58261.95	92888.22	1.59	1.49	95.34
08/04/07	9.07	541000.95	865.97	59669.22	98314.82	1.65	1.57	99.14
08/05/07	7.53	421813.12	746.26	55992.89	101427.72	1.81	1.73	91.66
08/06/07	7.02	365867.83	690.35	52142.68	97508.46	1.87	1.79	86.51
08/07/07	9.97	540527.63	961.86	54233.54	91778.98	1.69	1.60	86.79
08/08/07	12.08	690743.74	1133.17	57165.00	87082.09	1.52	1.43	91.25
08/09/07	12.40	723507.09	1195.79	58347.35	85745.25	1.47	1.37	93.36
08/10/07	13.62	797818.48	1286.68	58591.32	88556.45	1.51	1.41	95.38
08/11/07	12.83	750641.32	1237.43	58491.53	90975.66	1.56	1.45	95.60
08/12/07	12.93	779872.73	1232.51	60299.44	90239.55	1.50	1.40	99.45
08/13/07	12.48	770811.26	1217.52	61747.23	89362.94	1.45	1.36	101.31
08/14/07	12.42	730824.77	1425.22	58858.37	89707.53	1.52	1.41	96.71
08/15/07	13.58	806481.80	1349.36	59372.89	87823.87	1.48	1.37	96.93
08/16/07	13.68	821347.20	1278.37	60025.37	86871.42	1.45	1.35	97.85
08/17/07	15.37	897449.17	1418.68	58402.33	88895.06	1.52	1.41	96.11
08/18/07	12.47	752441.26	1186.80	60356.25	88485.75	1.47	1.37	99.35
08/19/07	12.07	724879.28	1131.57	60072.87	89624.53	1.49	1.40	99.47
08/20/07	10.80	641912.96	1058.60	59436.38	90495.48	1.52	1.44	97.15
08/21/07	11.95	729384.47	1137.74	61036.36	89067.54	1.46	1.37	99.76
08/22/07	14.87	949833.41	1525.87	63890.14	93056.27	1.46	1.35	99.83
08/23/07	17.80	1121914.00	1749.89	63028.88	93615.39	1.49	1.36	97.71
08/24/07	18.22	1157458.15	1788.77	63538.42	97949.71	1.54	1.41	98.27
08/25/07	14.90	821253.25	1419.51	55117.67	95375.50	1.73	1.59	90.45
08/26/07	13.68	745568.66	1283.66	54487.36	93007.78	1.71	1.58	89.26
08/27/07	16.37	951854.37	1517.08	58158.11	88059.84	1.51	1.39	95.20
08/28/07	18.23	1095133.73	1729.73	60062.18	89705.99	1.49	1.36	97.11
08/29/07	18.65	1163738.07	1801.33	62398.82	92319.70	1.48	1.35	98.88
08/30/07	19.50	1213660.63	1900.14	62239.01	95804.64	1.54	1.39	98.31
08/31/07	14.07	839231.63	1461.25	59661.02	94227.04	1.58	1.46	97.60

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 18							
Site	Luke AFB							
Analysis Period:	September 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
08/31/07	2.37	147873.63	2119.93	62481.82	88478.34	1.42	1.27	106.15
09/01/07	14.50	863074.50	1349.62	59522.38	93798.90	1.58	1.46	98.14
09/02/07	14.18	823042.43	1321.55	58028.84	95547.76	1.65	1.52	95.27
09/03/07	13.13	775430.15	1228.26	59042.90	92427.41	1.57	1.46	97.33
09/04/07	14.85	891751.87	1458.16	60050.63	90391.56	1.51	1.39	94.01
09/05/07	17.33	1027032.42	1705.86	59251.87	91216.05	1.54	1.40	93.52
09/06/07	17.05	985228.60	1633.81	57784.67	88806.42	1.54	1.40	92.99
09/07/07	16.50	902580.93	1526.36	54701.87	88779.96	1.62	1.48	90.25
09/08/07	13.68	759627.10	1275.21	55514.77	87295.99	1.57	1.46	90.35
09/09/07	14.38	817268.84	1338.14	56820.55	86710.80	1.53	1.41	93.31
09/10/07	15.72	899018.94	1467.58	57201.63	85981.13	1.50	1.38	94.22
09/11/07	8.75	477507.22	1259.00	54572.25	85790.39	1.57	1.45	90.96
09/24/07	1.47	55223.27	310.78	37652.23	82466.48	2.19	2.13	77.44
09/25/07	5.57	259550.68	593.28	46625.87	78657.51	1.69	1.61	77.99
09/26/07	6.93	341460.41	732.21	49249.10	77868.92	1.58	1.50	80.17
09/27/07	7.20	358505.24	735.96	49792.39	79172.42	1.59	1.51	80.77
09/28/07	7.80	386063.69	775.52	49495.34	79446.67	1.61	1.52	82.07
09/29/07	7.57	376723.79	754.40	49787.28	82353.06	1.65	1.57	83.21
09/30/07	5.70	271508.35	632.53	47633.04	81146.70	1.70	1.63	78.55
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

Unit:	GHP 18							
Site	Luke AFB							
Analysis Period:	October 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
09/30/07	0.70	38975.14	2208.12	55678.78	82037.34	1.47	1.37	93.39
10/01/07	5.83	300444.58	2202.45	51504.79	84603.91	1.64	1.57	84.45
10/02/07	6.63	327262.47	2201.69	49336.05	89154.24	1.81	1.72	85.60
10/03/07	11.25	579440.34	2190.32	51505.81	84487.01	1.64	1.53	84.49
10/04/07	11.98	632502.27	2189.54	52855.34	83785.24	1.59	1.47	87.45
10/05/07	9.38	487906.60	2205.78	51997.15	85184.65	1.64	1.54	84.16
10/06/07	4.70	221844.55	2200.31	47200.97	82771.38	1.75	1.69	72.37
10/07/07	2.83	134286.04	2187.64	47395.07	77555.09	1.64	1.60	70.11
10/08/07	3.87	192932.08	2190.96	50112.23	78543.09	1.57	1.52	75.10
10/09/07	7.17	366929.44	2200.36	51199.46	77810.70	1.52	1.45	78.49
10/10/07	6.42	329461.98	2177.21	51344.72	77546.96	1.51	1.45	76.87
10/11/07	4.07	202022.03	2194.21	49881.98	78790.19	1.58	1.53	75.99
10/12/07	2.93	148010.48	2263.34	50458.12	80789.18	1.60	1.57	76.02
10/13/07	3.92	188041.91	2245.63	48010.70	81605.71	1.70	1.65	74.56
10/14/07	4.02	192708.38	2255.39	47977.19	86743.09	1.81	1.75	72.45
10/15/07	4.65	226106.00	2175.28	48624.95	85360.81	1.76	1.70	74.11
10/16/07	3.50	168102.64	2189.71	48029.33	84759.88	1.76	1.72	72.69
10/17/07	3.35	159395.33	2156.41	47580.70	86366.11	1.82	1.77	72.26
10/18/07	4.18	207122.76	2200.10	49511.42	86450.75	1.75	1.69	71.15
10/19/07	4.17	206186.49	2275.70	49484.76	82347.55	1.66	1.61	73.82
10/20/07	3.88	195780.44	2279.09	50415.56	81707.21	1.62	1.58	74.81
10/21/07	4.03	193921.74	2286.06	48079.77	76271.41	1.59	1.54	76.00
10/22/07	1.35	70147.39	2234.23	51961.03	76768.61	1.48	1.46	67.83
10/23/07	1.05	50226.88	2256.54	47835.12	73199.02	1.53	1.51	69.27
10/24/07	3.50	179987.65	2245.39	51425.04	79388.03	1.54	1.51	77.10
10/25/07	3.08	153745.23	2195.78	50134.31	79558.91	1.59	1.55	75.55
10/26/07	3.70	186367.48	2165.31	50369.59	80311.52	1.59	1.55	73.67
10/27/07	3.67	183805.52	2155.56	50128.78	76386.24	1.52	1.48	73.83
10/28/07	4.77	242496.35	2165.64	50873.36	76600.12	1.51	1.45	76.36
10/29/07	1.60	78664.16	2278.79	49165.10	75847.88	1.54	1.50	73.78
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

Unit:	GHP 18
Site	Luke AFB
Analysis Period:	November 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
10/31/07	1.23	59826.75	2253.10	48508.17	85376.94	1.76	1.52	82.41
11/01/07	2.85	150144.78	2430.02	52682.38	84038.62	1.60	1.38	69.20
11/02/07	1.82	86580.43	2286.77	47658.95	84209.37	1.77	1.52	69.09
11/03/07	2.33	114638.08	2261.30	49130.60	80337.69	1.64	1.41	68.59
11/04/07	3.50	175256.11	2272.99	50073.17	79401.90	1.59	1.37	73.55
11/05/07	2.63	133602.29	2368.20	50735.05	85276.42	1.68	1.45	73.99
11/06/07	3.03	152987.57	2252.84	50435.46	86011.02	1.71	1.48	73.54
11/07/07	3.83	189415.87	2264.57	49412.83	86883.08	1.76	1.52	74.20
11/08/07	4.58	228187.04	2232.66	49786.26	85139.34	1.71	1.48	73.21
11/09/07	4.47	215158.00	2257.71	48169.70	83479.27	1.73	1.49	70.61
11/10/07	4.15	195438.01	2276.72	47093.50	81565.19	1.73	1.49	69.46
11/11/07	3.40	160833.33	2268.06	47303.92	80846.01	1.71	1.47	66.89
11/12/07	3.22	152101.75	2271.06	47285.52	81039.32	1.71	1.47	66.72
11/13/07	4.07	210919.05	2386.34	51865.34	86253.27	1.66	1.44	69.70
11/14/07	1.58	75314.96	2273.15	47567.34	89727.22	1.89	1.62	69.68
11/15/07	1.45	68993.57	2332.65	49281.12	92791.25	1.88	1.62	68.66
11/16/07	2.67	125283.35	2263.98	47276.74	87248.54	1.85	1.59	69.91
11/17/07	3.05	142512.26	2271.07	46982.06	87196.59	1.86	1.59	67.90
11/18/07	2.78	131748.96	2260.64	47334.96	85187.40	1.80	1.55	66.52
11/19/07	1.12	52000.00	2264.23	46567.16	86911.55	1.87	1.60	65.85
11/20/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	65.32
11/21/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	63.41
11/22/07	0.07	3066.67	2288.29	46000.00	93659.60	2.04	1.74	63.74
11/23/07	0.22	10283.33	2303.73	47461.54	86540.67	1.82	1.56	57.47
11/24/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	58.91
11/25/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	55.70
11/26/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	55.54
11/27/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	56.08
11/28/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	60.82
11/29/07	1.22	57233.33	2273.72	47041.10	80353.98	1.71	1.47	63.02
11/30/07	1.05	49433.33	2277.69	48508.17	88790.75	1.86	1.60	66.12

Note: F.O. stands for the unit was operable but the tenant was running the fans only.

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 18
Site	Luke AFB
Analysis Period:	December 2007
Mode of Operation:	Heating and cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
11/30/07	0.87	46116.67	53211.54	2519.59	106009.38	2.03	1.71	63.11
12/01/07	2.07	97283.33	47072.58	2308.52	92759.95	2.01	1.69	61.34
12/02/07	0.20	9200.00	46000.00	2310.69	92004.05	2.00	1.71	51.56
12/03/07	0.03	1672.45	50173.55	3502.69	43660.99	0.86	0.70	53.92
12/04/07	1.30	93875.35	72211.81	3386.37	52408.47	0.72	0.63	56.35
12/05/07	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	56.48
12/06/07	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	56.83
12/07/07	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	58.57
12/08/07	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	55.62
12/09/07	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	50.09
12/10/07	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	50.43
12/11/07	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	U.O.	50.42
12/12/07	1.77	128384.26	72670.34	3284.37	57277.82	0.79	0.68	47.55
12/13/07	9.52	586486.07	61627.26	3220.29	57001.72	0.92	0.78	49.20
12/14/07	11.35	693991.30	61144.61	3089.07	54000.86	0.88	0.75	49.09
12/15/07	12.30	770318.18	62627.49	3103.63	49563.64	0.79	0.68	47.66
12/16/07	12.75	793008.77	62196.77	3082.54	47826.78	0.77	0.66	46.59
12/17/07	9.43	586935.75	62219.34	3080.04	49008.66	0.79	0.67	49.07
12/18/07	9.70	607781.15	62657.85	3080.59	49808.10	0.79	0.68	48.82
12/19/07	8.03	509417.26	63412.94	3077.14	51195.47	0.81	0.69	49.50
12/20/07	8.57	562582.49	65671.11	3088.53	54022.29	0.82	0.71	50.28
12/21/07	1.02	76024.69	74778.39	3175.60	91020.27	1.22	1.06	53.41
12/22/07	1.73	96929.77	55921.02	3205.57	66370.37	1.19	0.99	46.42
12/23/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	44.29
12/24/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	47.15
12/25/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	49.48
12/26/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	40.93
12/28/07	0.63	39226.98	61937.33	3249.44	64171.13	1.04	0.88	47.20
12/29/07	16.07	978860.04	60924.90	3130.47	44136.60	0.72	0.62	43.92
12/30/07	14.73	873712.66	59301.76	3131.46	42942.01	0.72	0.61	44.01
12/31/07	11.98	710984.70	59331.13	3127.28	44155.24	0.74	0.63	42.67

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 18
Site:	Luke AFB
Analysis Period:	January 2008
Mode of Operation:	Heating

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
01/01/08	12.73	805722.06	63276.60	3088.06	51286.63	0.81	0.69	54.92
01/02/08	5.87	364871.00	62193.92	3070.43	46816.31	0.75	0.64	57.19
01/03/08	4.22	245557.54	58234.99	3067.63	61861.17	1.06	0.90	54.66
01/04/08	1.98	114115.20	57537.08	3140.96	73108.71	1.27	1.07	58.05
01/05/08	1.57	94204.33	60130.42	3123.93	92945.49	1.55	1.31	58.59
01/06/08	1.28	77560.20	60436.52	3084.56	101969.98	1.69	1.44	57.88
01/07/08	0.27	16834.37	63128.89	3167.09	101609.89	1.61	1.37	56.77
01/09/08	0.88	52163.85	59053.42	3073.10	90720.18	1.54	1.30	58.33
01/10/08	4.23	237195.64	56030.47	3113.19	73120.65	1.31	1.10	50.88
01/11/08	4.28	237403.80	55425.01	3119.20	69126.06	1.25	1.05	51.15
01/12/08	4.95	273241.87	55200.38	3126.79	73226.61	1.33	1.11	51.26
01/13/08	3.70	209830.46	56710.93	3117.11	79069.32	1.39	1.17	55.03
01/14/08	6.42	388827.41	60596.48	3075.46	78605.71	1.30	1.11	59.30
01/15/08	5.02	282223.43	56257.16	3111.72	64460.30	1.15	0.96	54.63
01/16/08	5.10	285495.69	55979.55	3106.28	66201.95	1.18	0.99	50.21
01/17/08	7.35	460061.60	62593.41	3107.78	105320.88	1.68	1.44	47.26
01/18/08	3.97	228338.23	57564.26	3110.41	55881.49	0.97	0.82	44.35
01/19/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	46.92
01/20/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	45.66
01/21/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	46.09
01/22/08	2.83	199964.01	70575.53	3365.23	74307.59	1.05	0.91	46.05
01/23/08	11.02	654525.21	59412.27	3490.58	50453.98	0.85	0.71	49.66
01/24/08	3.90	225729.19	57879.28	3473.31	72487.38	1.25	1.04	54.03
01/25/08	5.58	312240.85	55923.74	3455.95	76601.78	1.37	1.13	51.15
01/26/08	5.25	296182.09	56415.64	3483.42	76149.96	1.35	1.11	53.12
01/27/08	14.52	968426.64	66711.36	3468.09	7000.17	0.10	0.09	54.41
01/28/08	10.05	651586.02	64834.43	3429.35	50211.45	0.77	0.66	56.85
01/29/08	4.73	270669.59	57183.72	3443.54	79330.25	1.39	1.15	53.83
01/30/08	5.50	299583.05	54469.65	3478.96	64003.23	1.18	0.96	47.71
01/31/08	7.43	422663.24	56860.53	3492.53	65629.69	1.15	0.95	45.96
12/31/07	1.38	85337.52	61689.77	3060.42	50472.37	0.82	0.70	60.04

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 18
Site	Luke AFB
Analysis Period:	February 2008
Mode of Operation:	Heating and Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
01/31/08	0.07	3902.64	58539.60	3533.20	89476.10	1.53	1.27	54.98
02/01/08	8.05	446820.67	55620.83	3467.93	64248.48	1.16	0.95	46.60
02/02/08	7.83	438083.90	55925.60	3440.84	66402.37	1.19	0.98	49.27
02/03/08	6.52	370448.65	56846.34	3415.91	70519.51	1.24	1.03	50.83
02/04/08	5.55	322459.55	58100.82	3401.70	80236.90	1.38	1.15	54.98
02/05/08	7.95	443084.50	55733.90	3416.72	68044.57	1.22	1.01	45.27
02/06/08	8.48	483948.51	57046.98	3413.13	65207.69	1.14	0.95	46.49
02/07/08	7.12	398085.28	55937.04	3390.03	64216.47	1.15	0.95	49.32
02/08/08	5.90	327990.11	55591.54	3392.17	66344.30	1.19	0.99	51.78
02/09/08	4.63	260224.06	56163.47	3381.13	71928.31	1.28	1.06	55.00
02/10/08	4.42	256299.24	58030.02	3389.61	59886.94	1.03	0.86	58.25
02/11/08	3.15	180089.56	57171.29	3357.71	74494.02	1.30	1.09	59.69
02/12/08	2.60	149953.00	57674.23	3344.51	75570.69	1.31	1.09	61.12
02/13/08	1.72	97850.29	57000.17	3367.60	74781.71	1.31	1.09	60.00
02/14/08	1.77	95376.25	53986.55	2889.37	86368.35	1.60	1.35	60.84
02/15/08	2.13	122229.81	57295.22	3270.46	80383.69	1.40	1.17	53.34
02/16/08	12.47	802584.85	64378.46	3356.68	13992.96	0.22	0.18	49.23
02/17/08	8.72	544036.77	62413.40	3324.84	30616.82	0.49	0.42	51.70
02/18/08	3.22	181689.56	56483.80	3378.34	73901.46	1.31	1.09	54.59
02/19/08	2.20	115994.18	52724.63	2962.75	80519.79	1.53	1.28	56.60
02/20/08	0.95	50569.76	53231.32	2998.73	94126.09	1.77	1.48	58.81
02/21/08	1.32	72419.13	55001.87	3234.25	89773.87	1.63	1.36	56.63
02/22/08	1.03	56264.91	54449.91	3047.59	89435.03	1.64	1.38	54.33
02/23/08	2.30	128009.81	55656.44	3373.14	80072.75	1.44	1.19	52.63
02/24/08	1.03	60461.89	58511.51	3399.57	99450.00	1.70	1.42	58.44
02/25/08	2.17	127460.72	58828.03	3356.47	85538.88	1.45	1.22	59.62
02/26/08	2.38	132748.62	55698.72	3060.27	85502.92	1.54	1.29	63.03
02/27/08	2.93	156143.88	53230.87	2811.39	88098.07	1.66	1.40	64.73
02/28/08	2.63	133049.08	50524.97	2765.81	89785.44	1.78	1.50	63.13
02/29/08	2.12	118140.41	55814.37	3096.19	86942.68	1.56	1.31	61.14

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 18
Site	Luke AFB
Analysis Period:	March 2008
Mode of Operation:	Heating and Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
02/29/08	1.40	81578.81	58270.58	2635.48	100020.35	1.72	1.49	79.01
03/01/08	1.22	61969.76	50934.05	2736.04	98305.54	1.93	1.63	65.88
03/02/08	0.08	5466.29	65595.52	3450.64	99455.77	1.52	1.29	64.60
03/03/08	4.15	243737.08	58731.83	3332.13	68699.34	1.17	0.98	57.23
03/04/08	2.38	131450.88	55154.22	3310.86	65723.51	1.19	0.99	57.06
03/05/08	2.47	137363.47	55687.89	3305.41	66574.45	1.20	0.99	58.26
03/06/08	3.63	204824.02	56373.58	3216.55	65883.64	1.17	0.98	57.85
03/07/08	3.73	205454.80	55032.54	3254.18	65876.48	1.20	1.00	57.45
03/09/08	3.15	204811.08	65019.39	3249.53	46781.56	0.72	0.61	64.22
03/10/08	1.18	69964.66	59125.06	3349.03	77835.26	1.32	1.10	65.08
03/11/08	0.55	32028.34	58233.35	3381.62	83227.76	1.43	1.19	65.92
03/12/08	0.52	27654.28	53524.41	2827.13	92619.16	1.73	1.47	68.22
03/13/08	0.40	21319.23	53298.07	2791.24	87557.29	1.64	1.39	68.58
03/14/08	1.32	90152.45	68470.22	3053.13	101042.85	1.48	1.28	71.33
03/15/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	64.61
03/16/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	56.38
03/17/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	51.18
03/18/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	57.21
03/19/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	62.43
03/20/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	65.20
03/21/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	67.74
03/22/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	68.37
03/23/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	72.53
03/24/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	69.46
03/25/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	65.49

Note: U.O. stands for an unscheduled outage

Appendix D: GHP 19 Performance Data

Unit:	GHP 19
Site	Nellis AFB
Analysis Period:	June 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
05/31/07	0.62	37092.63	2042.60	60150.21	73249.71	1.22	1.10	95.62
06/01/07	0.00	0.00	U.O. Outage	U.O.	U.O.	U.O.	U.O.	91.11
06/02/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	93.40
06/03/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	92.78
06/04/07	3.37	238102.38	2444.28	70723.48	59371.23	0.94	0.84	106.27
06/06/07	1.50	67190.46	2120.59	44793.64	74166.47	1.72	1.47	73.64
06/07/07	2.43	109312.80	2078.63	44923.07	81728.60	1.87	1.60	71.93
06/08/07	3.55	180728.36	2060.34	50909.40	77208.01	1.56	1.36	77.74
06/09/07	2.45	137237.47	2024.88	56015.29	67479.93	1.24	1.10	82.64
06/10/07	2.98	171201.36	2024.81	57385.93	67649.63	1.21	1.08	85.70
06/11/07	0.13	6706.82	1912.35	50301.18	69741.34	1.57	1.34	79.98
06/13/07	0.22	10986.18	2070.87	50705.45	75995.43	1.54	1.34	83.53
06/14/07	1.43	76730.79	2090.18	53533.11	78447.90	1.50	1.32	94.48
06/15/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	97.22
06/16/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	94.94
06/17/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	93.23
06/18/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	88.37
06/20/07	0.68	37949.19	2034.28	55535.40	70166.90	1.28	1.13	92.06
06/21/07	6.45	380091.95	1976.76	58928.99	70126.77	1.21	1.08	89.91
06/22/07	7.40	449652.15	1965.91	60763.80	70530.21	1.18	1.06	94.16
06/23/07	5.88	352795.80	1979.22	59965.29	67696.23	1.15	1.03	95.68
06/24/07	5.68	335632.52	1996.06	59055.57	67532.92	1.17	1.04	94.85
06/25/07	1.62	84921.93	2090.82	52529.03	74310.85	1.45	1.28	92.22
06/26/07	3.12	199093.82	2131.64	63880.37	70529.28	1.12	1.00	91.25
06/27/07	4.20	245276.44	2050.76	58399.15	71008.26	1.25	1.11	91.21
06/28/07	7.38	443451.68	1956.22	60061.18	72129.82	1.22	1.09	93.01
06/29/07	8.80	533413.43	1949.56	60615.16	72076.03	1.21	1.08	94.75
06/30/07	5.07	307903.78	1948.22	60770.48	64072.10	1.08	0.97	97.23

Note: U.O. stands for an unscheduled outage

Unit:	GHP 19							
Site	Nellis AFB							
Analysis Period:	July 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
06/30/07	0.75	43897.26	1973.37	58529.68	66489.35	1.14	1.02	98.22
07/01/07	5.47	334861.11	1966.88	61255.08	64848.28	1.08	0.97	96.13
07/02/07	9.28	575547.50	1982.74	61997.94	71679.78	1.17	1.05	96.76
07/03/07	7.88	486040.53	1939.37	61654.19	66663.98	1.10	0.99	94.33
07/04/07	6.90	424423.27	1956.40	61510.62	61508.89	1.02	0.92	97.44
07/05/07	9.53	618859.63	2042.18	64915.35	72905.50	1.14	1.02	100.37
07/06/07	10.55	698942.12	2117.44	66250.44	77589.89	1.18	1.06	102.46
07/07/07	9.30	634912.79	2171.46	68270.19	82071.91	1.22	1.10	101.47
07/08/07	8.43	523589.84	1943.21	62085.75	75047.18	1.22	1.10	98.06
07/09/07	6.30	376150.62	2011.26	59706.45	81881.33	1.39	1.25	93.68
07/10/07	7.67	464912.06	1984.01	60640.70	82486.26	1.38	1.24	96.45
07/11/07	2.52	145543.43	1928.35	57831.83	80406.65	1.40	1.25	95.30
07/12/07	9.53	599299.02	2085.39	62863.53	85136.52	1.38	1.23	97.13
07/13/07	9.12	554947.64	1931.28	60871.77	72239.32	1.21	1.08	95.29
07/14/07	7.05	428029.62	1980.90	60713.42	76164.45	1.28	1.15	97.96
07/15/07	7.63	461373.30	1939.40	60441.92	78371.07	1.32	1.19	98.67
07/16/07	11.43	761989.24	2197.91	66646.29	90984.31	1.38	1.24	100.06
07/17/07	12.42	834302.53	2231.77	67192.15	90171.81	1.36	1.22	99.44
07/18/07	10.85	683671.57	2047.71	63011.20	77317.88	1.24	1.11	97.03
07/19/07	10.08	614246.35	1944.16	60916.99	73451.40	1.22	1.09	97.31
07/20/07	12.07	748267.42	2046.57	62011.11	79468.36	1.29	1.16	95.08
07/21/07	8.83	537788.44	1998.12	60881.71	89004.38	1.48	1.33	98.16
07/22/07	9.28	537258.18	1957.38	57873.41	90122.76	1.58	1.41	94.72
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

Unit:	GHP 19							
Site	Nellis AFB							
Analysis Period:	August 2007							
Mode of Operation	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
08/01/07	0.38	17674.79	1998.17	46108.16	84339.30	1.86	1.61	79.18
08/02/07	2.18	118970.52	1983.17	54490.32	92121.41	1.69	1.50	88.50
08/03/07	9.20	600974.96	2398.33	65323.37	96566.37	1.51	1.34	91.45
08/04/07	7.20	436479.45	1928.22	60622.15	82908.59	1.39	1.25	96.77
08/05/07	6.52	389720.73	1940.27	59803.69	83046.65	1.40	1.26	96.82
08/06/07	6.82	381998.73	1991.11	56038.93	85256.30	1.54	1.37	91.47
08/07/07	7.48	429182.04	1975.59	57351.72	82472.81	1.45	1.30	90.26
08/08/07	6.20	363839.39	1992.92	58683.77	80377.15	1.39	1.24	89.68
08/09/07	7.47	465467.84	2121.97	62339.44	83171.31	1.35	1.20	91.52
08/10/07	8.58	514530.04	1973.37	59945.25	80982.88	1.36	1.22	93.70
08/11/07	3.03	185390.00	1976.79	61117.58	91599.30	1.57	1.40	95.15
08/12/07	3.83	234979.91	1986.04	61299.11	97405.12	1.64	1.47	96.92
08/13/07	9.23	641770.59	2375.27	69505.84	93229.14	1.36	1.22	96.45
08/14/07	9.45	623260.28	2362.32	65953.47	90606.44	1.40	1.24	93.69
08/15/07	7.47	514364.16	2392.70	68888.06	93342.77	1.39	1.24	95.42
08/16/07	8.75	586511.32	2246.06	67029.87	90072.03	1.36	1.22	97.97
08/17/07	7.17	447875.90	2118.38	62494.31	85616.87	1.40	1.25	92.41
08/18/07	1.88	114956.61	1991.36	61038.91	93994.89	1.59	1.42	92.30
08/19/07	2.52	153882.01	2000.51	61145.17	81190.25	1.36	1.22	95.84
08/20/07	9.57	571478.55	1999.73	59736.43	75150.75	1.27	1.14	93.41
08/21/07	8.52	520872.52	2106.26	61159.20	76266.69	1.27	1.13	90.16
08/22/07	7.48	470974.12	2156.92	62936.41	80393.40	1.30	1.16	92.57
08/23/07	10.70	687804.57	2184.11	64280.80	81806.23	1.28	1.15	95.62
08/24/07	14.63	1139750.40	2706.14	77887.27	99854.18	1.30	1.16	95.06
08/25/07	15.00	932894.76	2165.17	62192.98	84039.92	1.36	1.22	94.36
08/26/07	14.03	786704.23	1942.74	56059.68	79389.49	1.43	1.28	91.64
08/27/07	9.98	544722.33	2276.68	54563.17	91198.91	1.71	1.49	83.98
08/28/07	13.07	893701.47	2528.74	68395.52	95299.39	1.41	1.25	91.16
08/29/07	9.05	605258.70	2374.02	66879.41	93281.01	1.42	1.26	95.09
08/30/07	3.63	216375.71	2027.19	59552.95	82902.23	1.41	1.26	93.51
08/31/07	6.00	356781.54	1956.50	59463.59	81437.64	1.40	1.25	93.57
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

Unit:	GHP 19							
Site	Nellis AFB							
Analysis Period:	September 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
09/01/07	4.88	291165.15	1978.62	59624.26	84770.50	1.42	1.27	95.16
09/02/07	4.95	291230.61	1991.07	58834.47	84769.46	1.44	1.29	95.34
09/03/07	6.98	412850.83	1987.00	59119.45	81644.56	1.38	1.24	94.76
09/04/07	7.70	462744.38	1958.35	60096.67	78786.93	1.31	1.18	96.34
09/05/07	9.17	559360.31	2123.84	61021.12	84922.67	1.39	1.24	92.69
09/06/07	6.98	394518.98	1964.57	56494.36	75975.88	1.34	1.20	87.31
09/07/07	7.73	432395.74	1959.58	55913.24	76235.02	1.36	1.21	88.28
09/08/07	13.07	853027.92	2400.59	65282.75	85283.58	1.31	1.16	89.21
09/09/07	6.90	377801.02	2007.19	54753.77	84650.08	1.55	1.37	87.75
09/10/07	8.80	490716.66	1975.32	55763.26	79132.09	1.42	1.26	88.45
09/11/07	11.40	659864.70	1894.28	57882.87	73029.58	1.26	1.13	91.53
09/12/07	6.58	381178.91	1977.47	57900.59	74785.86	1.29	1.15	87.63
09/13/07	7.78	495246.52	2298.88	63629.10	86438.89	1.36	1.21	92.33
09/14/07	7.32	415542.82	1975.33	56794.01	76679.82	1.35	1.20	89.23
09/15/07	2.27	126368.56	2024.98	55750.84	70816.67	1.27	1.13	84.36
09/16/07	2.72	144757.22	2075.88	53284.87	67234.78	1.26	1.11	83.63
09/17/07	4.87	241349.39	2030.88	49592.34	75468.54	1.52	1.33	78.72
09/18/07	4.32	216383.90	2030.10	50127.54	79530.59	1.59	1.39	79.42
09/19/07	4.68	243650.48	2009.94	52025.01	78826.13	1.52	1.33	80.73
09/20/07	3.98	191111.66	2063.99	47977.82	85203.81	1.78	1.54	74.87
09/21/07	4.87	229222.12	2042.69	47100.43	82384.85	1.75	1.52	74.48
09/22/07	0.30	14224.56	2121.86	47415.19	99229.60	2.09	1.81	69.97
09/23/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	68.29
09/24/07	2.43	94922.28	2062.76	39009.15	90096.69	2.31	1.95	67.83
09/25/07	2.55	107891.98	2081.19	42310.58	83999.20	1.99	1.69	69.36
09/26/07	3.73	179423.57	2034.57	48059.88	80854.89	1.68	1.46	71.44
09/27/07	3.28	155839.18	2018.28	47463.71	83610.41	1.76	1.53	73.88
09/28/07	4.17	211042.88	2046.83	50650.29	80331.06	1.59	1.39	76.63
09/29/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	71.18
09/30/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	68.10

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 19							
Site	Nellis AFB							
Analysis Period:	October 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
09/30/07	0.03	1533.33	2138.51	46000.00	70785.93	1.54	1.33	68.59
10/01/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	63.57
10/04/07	4.67	238340.78	2017.70	51073.03	80211.30	1.57	1.38	81.89
10/05/07	2.47	115050.00	2077.54	46641.89	86450.13	1.85	1.61	66.75
10/06/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	60.55
10/07/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	61.92
10/08/07	0.37	16241.43	2155.25	46404.10	67510.42	1.45	1.26	66.74
10/09/07	2.33	113196.00	2069.45	48512.57	83291.57	1.72	1.50	70.24
10/10/07	3.10	148524.25	2063.35	48696.47	77934.20	1.60	1.40	72.04
10/11/07	0.37	17500.00	2058.63	47727.27	67560.27	1.42	1.23	68.58
10/12/07	1.48	70527.81	2091.38	47546.84	72663.34	1.53	1.33	69.88
10/13/07	0.18	8433.33	2117.16	46000.00	76491.89	1.66	1.44	68.68
10/14/07	1.03	48166.67	2104.10	46612.90	86104.08	1.85	1.60	68.84
10/15/07	6.37	343572.57	2540.84	54105.92	88813.40	1.64	1.41	70.06
10/16/07	2.22	103550.00	2071.81	46714.29	86949.87	1.86	1.62	70.35
10/17/07	1.70	79783.33	2079.12	46931.37	90195.73	1.92	1.67	65.82
10/18/07	2.00	94216.67	2096.82	47108.33	87110.42	1.85	1.61	63.74
10/19/07	1.20	55833.33	2104.99	46527.78	80055.30	1.72	1.49	66.48
10/20/07	0.07	3066.67	2121.74	46000.00	63706.55	1.38	1.20	70.35
10/21/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	59.23
10/22/07	0.77	35900.00	2146.53	46826.09	81854.56	1.75	1.51	60.34
10/23/07	1.75	81558.95	2104.80	47053.24	83947.64	1.78	1.55	67.63
10/24/07	2.23	106447.70	2083.67	47663.15	82020.93	1.72	1.50	70.67
10/25/07	2.03	96068.97	2058.10	47637.51	84480.88	1.77	1.55	67.90
10/26/07	2.45	117537.67	2167.86	47974.56	83726.65	1.75	1.51	69.92
10/27/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	71.99
10/28/07	0.07	3066.67	2165.97	46000.00	78457.46	1.71	1.47	71.29
10/29/07	3.00	139669.32	2065.17	46556.44	84996.12	1.83	1.59	70.23
10/30/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	64.59

Note: F.O. stands for the unit was operable but the tenant was running the fans only.

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 19
Site:	Nellis AFB
Analysis Period:	November 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
10/31/07	0.20	8750.00	2142.60	47727.27	91304.79	1.91	1.66	63.09
11/01/07	3.05	143783.33	2078.69	47142.08	86962.34	1.84	1.60	65.57
11/02/07	1.77	85583.33	2225.55	48443.40	88685.20	1.83	1.58	68.46
11/03/07	0.55	24533.33	2135.45	46000.00	76887.10	1.67	1.44	68.17
11/04/07	0.05	2300.00	2189.71	46000.00	73455.88	1.60	1.37	65.20
11/05/07	2.27	106440.79	2087.61	46959.17	81291.82	1.73	1.50	66.59
11/06/07	1.92	91082.69	2077.84	47521.40	80413.92	1.69	1.47	66.48
11/07/07	2.12	99860.47	2054.83	47552.60	77654.22	1.63	1.42	68.26
11/08/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	F.O.
11/09/07	6.82	325250.00	2195.26	48185.19	79306.48	1.65	1.42	66.03
11/10/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	61.52
11/11/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	63.12
11/12/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	62.83
11/13/07	1.52	50650.00	2566.74	47484.38	87068.43	1.83	1.55	59.94
11/14/07	0.88	52850.00	3369.58	60980.77	107158.75	1.76	1.48	64.70
11/15/07	1.60	104000.00	3666.83	65000.00	112680.55	1.73	1.45	63.58
11/16/07	1.58	102600.00	3721.73	64800.00	115264.73	1.78	1.49	60.43
11/17/07	0.17	10833.33	3844.68	65000.00	115296.03	1.77	1.48	62.06
11/18/07	0.38	24916.67	3832.21	65000.00	92856.18	1.43	1.19	60.99
11/19/07	1.50	96416.67	3738.33	65000.00	115004.73	1.77	1.48	61.83
11/20/07	1.62	104766.67	3724.48	64804.12	115216.08	1.78	1.49	63.33
11/21/07	0.70	45500.00	3772.03	65000.00	107045.25	1.65	1.37	52.06
11/22/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	47.55
11/23/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	48.95
11/24/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	50.16
11/25/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	48.15
11/26/07	0.07	4333.33	4002.89	65000.00	104463.78	1.61	1.33	49.34
11/27/07	0.35	22750.00	3894.31	65000.00	104315.86	1.60	1.33	47.95
11/28/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	51.12
11/29/07	0.18	11916.67	3973.74	65000.00	107826.58	1.66	1.37	46.68
11/30/07	0.12	7583.33	3919.71	65000.00	115258.63	1.77	1.47	49.91

Note: F.O. stands for the unit was operable but the tenant was running the fans only.

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 19							
Site	Nellis AFB							
Analysis Period:	December 2007							
Mode of Operation:	Heating and cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
12/03/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	34.68
12/04/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	48.15
12/05/07	0.28	13033.33	46000.00	2201.98	108771.81	2.36	2.03	52.68
12/06/07	2.85	137633.33	48292.40	2244.43	89425.60	1.85	1.60	52.91
12/07/07	1.80	84383.33	46879.63	2142.57	99679.69	2.13	1.84	57.38
12/08/07	0.87	40500.00	46730.77	2224.28	104978.78	2.25	1.93	46.03
12/09/07	0.10	4916.67	49166.67	2288.37	88447.20	1.80	1.55	45.86
12/10/07	1.50	71180.41	47453.61	2165.42	96290.24	2.03	1.76	46.98
12/11/07	0.38	17950.00	46826.09	2234.59	106205.61	2.27	1.95	43.58
12/12/07	0.43	19933.33	46000.00	2236.47	99746.02	2.17	1.86	40.80
12/13/07	0.68	32066.67	46926.83	2222.76	108609.98	2.31	1.99	41.50
12/14/07	0.72	37790.45	52730.86	3011.18	81134.78	1.54	1.29	42.14
12/15/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	39.56
12/16/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	38.75
12/17/07	0.87	39866.67	46000.00	2198.04	87744.19	1.91	1.64	43.56
12/18/07	1.72	81590.00	47528.15	2383.76	76396.64	1.61	1.37	48.01
12/19/07	4.98	231766.67	46508.36	2105.62	72684.03	1.56	1.35	48.26
12/20/07	3.07	142016.67	46309.78	2125.48	78490.87	1.69	1.47	49.79
12/21/07	0.30	14116.67	47055.56	2260.18	90221.46	1.92	1.65	42.06
12/22/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	38.38
12/23/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	40.57
12/24/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	45.44
12/25/07	0.93	50673.08	54292.59	3871.06	49836.51	0.92	0.74	42.69
12/26/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	38.17
12/27/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	37.31
12/28/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	32.73
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

Unit:	GHP 19
Site	Nellis AFB
Analysis Period:	January 2008
Mode of Operation:	Heating/Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
01/01/08	6.25	338878.48	54220.56	3861.68	43489.95	0.80	0.65	43.87
01/02/08	1.48	79451.23	53562.63	3833.24	40399.25	0.75	0.61	45.38
01/03/08	0.25	13652.14	54608.54	3986.69	48159.14	0.88	0.71	48.70
01/04/08	0.55	26413.40	48024.36	2361.44	73845.59	1.54	1.32	53.11
01/05/08	0.53	31555.20	59165.99	3861.42	75902.63	1.28	1.05	54.52
01/06/08	1.17	68851.15	59015.27	3848.97	77035.89	1.31	1.07	52.78
01/07/08	0.97	45100.00	46655.17	2164.13	77200.42	1.65	1.43	47.68
01/08/08	0.87	46349.40	53480.08	3955.47	53742.26	1.00	0.80	43.12
01/09/08	1.72	89560.60	52682.71	3866.47	49943.68	0.95	0.76	44.09
01/10/08	1.02	53040.66	52171.14	3903.02	41071.58	0.79	0.63	45.92
01/11/08	0.97	53922.36	55781.75	3929.35	48622.96	0.87	0.70	47.76
01/12/08	4.65	260546.21	56031.44	3809.49	47670.52	0.85	0.69	49.63
01/13/08	4.10	240277.00	58604.15	3817.61	53135.22	0.91	0.74	53.44
01/14/08	2.67	146322.39	54870.90	3809.86	43247.75	0.79	0.64	48.18
01/15/08	3.05	170589.55	55931.00	3798.67	47737.69	0.85	0.69	46.93
01/16/08	9.90	516057.97	52127.07	3767.84	37285.10	0.72	0.57	38.17
01/17/08	5.02	244987.22	48834.66	3833.52	33424.39	0.68	0.54	36.11
01/18/08	2.28	117216.07	51335.51	3843.59	34614.39	0.67	0.54	43.35
01/19/08	0.83	42859.21	51431.05	3986.35	46983.11	0.91	0.72	42.57
01/20/08	2.68	136851.73	51000.64	3860.06	41820.26	0.82	0.65	44.99
01/21/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	49.81
01/22/08	0.85	39416.67	46372.55	2223.57	83352.65	1.80	1.54	47.23
01/23/08	0.82	38200.00	46775.51	2234.86	83637.45	1.79	1.54	46.12
01/24/08	0.20	9516.67	47583.33	2262.25	80891.73	1.70	1.46	47.70
01/25/08	1.65	77166.67	46767.68	2205.38	82488.77	1.76	1.52	47.26
01/26/08	0.30	14574.97	48583.22	2266.89	74148.70	1.53	1.32	48.12
01/27/08	1.92	161644.81	84336.42	7794.00	24524.62	0.29	0.22	48.53
01/28/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	48.64
01/29/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	39.05
01/30/08	0.43	23206.31	53553.02	4000.54	42915.41	0.80	0.64	40.06
01/31/08	1.02	51445.90	50602.53	3908.46	38239.32	0.76	0.60	40.07

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 19							
Site	Nellis AFB							
Analysis Period:	February 2008							
Mode of Operation:	Cooling and Heating							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
01/31/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	38.11
02/01/08	0.62	31578.54	51208.45	3949.42	39542.07	0.77	0.61	43.64
02/02/08	0.72	38479.27	53692.01	3972.43	42439.02	0.79	0.63	45.04
02/03/08	1.47	81841.70	55801.16	3885.85	60296.71	1.08	0.87	47.42
02/04/08	2.77	148842.07	53798.34	3859.20	42266.64	0.79	0.63	43.87
02/05/08	2.63	137149.47	52082.08	3857.60	35928.46	0.69	0.55	40.63
02/06/08	1.73	88353.36	50973.10	3856.48	32250.86	0.63	0.50	41.24
02/07/08	0.60	30478.10	50796.83	3941.41	32036.58	0.63	0.50	45.41
02/08/08	0.20	12538.44	62692.18	3944.48	61982.42	0.99	0.81	50.43
02/09/08	0.40	18716.67	46791.67	2232.01	91618.46	1.96	1.68	51.90
02/10/08	0.78	36666.67	46808.51	2197.90	85955.94	1.84	1.58	53.59
02/11/08	0.57	26700.00	47117.65	2254.90	84327.57	1.79	1.54	56.63
02/12/08	2.03	95036.63	46739.32	2164.92	77747.46	1.66	1.44	59.56
02/13/08	1.43	67516.67	47104.65	2130.66	77970.06	1.66	1.43	55.87
02/14/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	43.41
02/15/08	1.63	89294.17	54669.90	3826.93	38930.01	0.71	0.57	48.84
02/16/08	0.50	26754.80	53509.61	3953.23	37143.30	0.69	0.55	49.69
02/17/08	0.73	41733.16	56908.85	3954.59	46609.87	0.82	0.66	52.53
02/18/08	0.30	17122.93	57076.43	3964.18	51376.15	0.90	0.73	51.56
02/19/08	0.27	13403.36	50262.58	2677.82	64514.45	1.28	1.09	55.84
02/20/08	1.38	65216.67	47144.58	2158.15	79617.88	1.69	1.46	53.81
02/21/08	0.97	44783.33	46327.59	2184.97	85645.87	1.85	1.59	51.45
02/22/08	0.63	29450.00	46500.00	2201.00	82078.24	1.77	1.52	51.36
02/23/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	44.65

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 19							
Site	Nellis AFB							
Analysis Period:	March 2008							
Mode of Operation:	Cooling and Heating							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
02/23/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	40.70
02/29/08	6.17	286200.00	46410.81	2102.57	80271.13	1.73	1.50	66.71
03/01/08	2.03	95116.67	46778.69	2170.77	80848.95	1.73	1.49	62.72
03/02/08	0.03	1971.82	59154.50	4029.48	69470.61	1.17	0.95	52.70
03/03/08	1.43	66250.00	46220.93	2188.42	76852.18	1.66	1.43	49.61
03/04/08	2.08	96466.67	46304.00	2158.61	79599.28	1.72	1.48	52.65
03/05/08	0.27	12583.33	47187.50	2249.30	71389.84	1.51	1.30	51.87
03/06/08	0.97	44783.33	46327.59	2208.92	79740.75	1.72	1.48	50.88
03/07/08	3.67	170250.00	46431.82	2136.52	77542.66	1.67	1.44	53.96
03/08/08	3.55	164566.67	46356.81	2119.40	76754.77	1.66	1.43	58.78
03/09/08	1.92	88033.33	46333.33	2149.48	78995.51	1.70	1.47	59.20
03/10/08	4.87	227983.33	46845.89	2126.67	76994.04	1.64	1.42	59.07
03/11/08	6.50	303433.33	46682.05	2108.53	77942.20	1.67	1.45	61.17
03/12/08	7.17	337889.25	47147.34	2124.17	75383.35	1.60	1.39	62.24
03/13/08	8.85	414007.27	46780.48	2067.54	77786.82	1.66	1.44	66.14
03/14/08	0.92	48141.35	52517.84	2354.72	52711.25	1.00	0.87	63.68
03/15/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	55.88
03/16/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	50.96
03/17/08	0.30	17877.66	59592.20	1729.71	9027.73	0.15	0.14	54.13
03/18/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	60.42
03/19/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	65.23
03/20/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	66.62
03/21/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	63.93
03/22/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	64.05
03/23/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	61.75
03/24/08	0.15	8578.73	57191.51	1779.75	4260.85	0.07	0.07	61.60
03/25/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	67.17
03/26/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	70.03
03/27/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	66.66
03/28/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	67.60
03/29/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	67.81
03/30/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	61.24
03/31/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	58.26
02/23/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	40.70

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Appendix E: GHP 20 Performance Data

Unit:	GHP 20
Site	Davis-Monthan AFB
Analysis Period:	June 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
05/31/07	6.80	610073.03	2456.16	89716.62	141805.28	1.58	1.44	89.09
06/04/07	1.93	186193.05	2433.67	96306.75	144214.88	1.50	1.37	99.08
06/11/07	8.67	556949.39	2367.75	64263.39	131815.91	2.09	1.85	75.79
06/12/07	1.97	69411.63	1951.76	35294.05	79286.07	2.28	1.91	68.15
06/13/07	7.97	732361.86	2450.99	91928.27	143947.30	1.57	1.44	92.37
06/14/07	0.03	1596.69	1980.50	47900.78	89547.89	1.87	1.64	80.93
06/27/07	15.20	1451326.83	2405.65	95482.03	142875.03	1.50	1.38	99.68
06/28/07	19.98	1784017.46	2346.42	89275.27	137032.88	1.55	1.42	94.80
06/29/07	4.28	286581.58	2209.77	66906.21	112990.12	1.70	1.52	85.85

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 20
Site	Davis-Monthan AFB
Analysis Period:	July 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
06/30/07	2.97	279982.65	2435.75	94376.17	135960.30	1.32	1.44	94.14
07/01/07	18.30	1515625.22	2299.47	82821.05	118693.58	1.31	1.43	94.43
07/02/07	19.08	1716349.64	2365.50	89939.72	134476.57	1.37	1.50	94.42
07/03/07	19.88	1773263.03	2345.32	89183.39	130991.50	1.35	1.47	94.67
07/04/07	10.80	796553.70	2293.33	73754.97	112981.50	1.38	1.53	96.30
07/05/07	14.65	1402292.79	2361.07	95719.64	141211.94	1.36	1.48	98.46
07/06/07	21.37	1859328.32	2315.22	87020.05	131196.11	1.38	1.51	94.15
07/07/07	20.85	1818446.37	2323.72	87215.65	121037.61	1.27	1.39	92.91
07/08/07	19.90	1706448.57	2343.35	85751.18	123071.59	1.31	1.44	90.19
07/09/07	20.37	1751873.55	2323.00	86016.70	129822.71	1.38	1.51	91.24
07/10/07	20.07	1726936.44	2335.15	86059.96	131827.68	1.40	1.53	90.11
07/11/07	19.58	1695793.34	2341.35	86593.70	132898.45	1.40	1.53	90.52
07/12/07	20.45	1747878.25	2329.16	85470.82	132509.10	1.42	1.55	89.97
07/13/07	12.83	1213409.60	2412.26	94551.40	143941.75	1.40	1.52	90.08
07/14/07	20.18	1735562.91	2338.89	85989.90	125631.80	1.34	1.46	91.13
07/15/07	19.32	1620886.37	2356.21	83911.29	127336.15	1.38	1.52	90.59
07/16/07	9.60	905199.10	2415.03	94291.57	146868.64	1.43	1.56	91.31
07/17/07	20.22	1788782.46	2316.62	88480.58	134583.39	1.40	1.52	93.41
07/18/07	20.08	1748031.52	2322.89	87038.91	131380.54	1.38	1.51	91.71
07/19/07	19.75	1688256.27	2335.06	85481.33	133004.75	1.42	1.56	88.08
07/20/07	18.53	1441999.79	2376.49	77805.74	129290.37	1.50	1.66	83.47

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 20							
Site	Davis-Monthan AFB							
Analysis Period:	September 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
09/11/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	0.00
09/13/07	10.87	1002564.90	2647.34	92260.57	140900.36	1.53	1.39	93.47
09/14/07	17.40	1378097.03	2462.50	79200.98	120359.96	1.52	1.37	88.49
09/15/07	17.73	1423440.83	2592.74	80269.22	135677.26	1.69	1.52	86.12
09/16/07	18.03	1317339.90	2389.61	73050.27	87247.72	1.19	1.07	80.83
09/17/07	16.25	1259436.35	2534.84	77503.78	197795.67	2.55	2.29	79.79
09/18/07	15.38	1164100.34	2358.48	75672.83	90701.07	1.20	1.08	81.43
09/19/07	17.67	1423209.56	2487.22	80559.03	86149.15	1.07	0.96	82.48
09/20/07	17.65	1424761.24	2478.68	80723.02	78228.81	0.97	0.87	81.81
09/21/07	18.05	1511161.66	2463.16	83720.87	83392.96	1.00	0.90	82.80
09/22/07	18.75	1560695.91	2468.49	83237.12	97178.21	1.17	1.06	83.96
09/23/07	18.43	1478761.96	2477.79	80222.17	83360.21	1.04	0.94	79.27
09/24/07	17.48	1210667.41	2366.25	69246.94	67532.56	0.98	0.87	75.62
09/25/07	17.07	1197998.68	2322.67	70195.23	70927.86	1.01	0.91	77.58
09/26/07	17.25	1218234.80	2318.86	70622.31	74462.81	1.05	0.95	79.07
09/27/07	17.38	1253966.25	2306.65	72136.12	78262.91	1.08	0.98	80.73
09/28/07	15.88	1057410.45	2275.49	66573.59	96876.81	1.46	1.30	82.08
09/29/07	16.23	1179284.54	2295.98	72645.86	82900.78	1.14	1.03	81.80
09/30/07	15.12	1079000.02	2300.12	71378.17	80809.57	1.13	1.02	80.42

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 20							
Site	Davis-Monthan AFB							
Analysis Period:	October 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
09/30/07	0.72	59096.87	2499.17	82460.75	68573.78	0.83	0.75	76.21
10/01/07	12.88	615430.60	1982.14	47769.52	100757.56	2.11	1.85	75.92
10/02/07	14.27	693725.85	1942.79	48853.93	94139.19	1.93	1.70	77.91
10/03/07	15.10	800987.29	1953.85	53045.52	104269.93	1.97	1.75	82.84
10/04/07	14.45	938394.65	2289.28	65166.29	130277.31	2.00	1.79	82.74
10/05/07	16.45	1224536.53	2331.63	74439.91	81871.11	1.10	0.99	80.18
10/06/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	68.23
10/07/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	65.67
10/08/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	74.98
10/09/07	7.00	579920.65	2597.46	82845.81	157683.12	1.90	1.72	80.56
10/10/07	15.80	1069630.35	2293.63	67698.12	106695.29	1.58	1.41	80.50
10/11/07	10.13	510775.70	1915.61	50405.50	89478.70	1.78	1.57	77.25
10/12/07	9.40	483181.28	1925.57	51402.26	82372.27	1.60	1.42	78.18
10/13/07	6.55	305101.68	1967.66	46580.41	88989.39	1.91	1.67	70.66
10/14/07	5.42	252016.67	1973.89	46526.15	94480.72	2.03	1.77	68.14
10/15/07	5.37	256732.91	1948.53	47838.43	90376.79	1.89	1.66	71.77
10/16/07	6.50	307393.13	1956.42	47291.25	90744.71	1.92	1.68	71.84
10/17/07	4.80	222066.67	1958.88	46263.89	92494.82	2.00	1.75	68.63
10/18/07	4.20	194783.33	1967.75	46376.98	95602.16	2.06	1.80	68.03
10/19/07	6.30	322580.68	1978.30	51203.28	92983.92	1.82	1.60	73.88
10/20/07	6.97	355803.45	1924.05	51072.27	84813.97	1.66	1.47	77.17
10/21/07	4.10	190183.33	1994.83	46386.18	90090.97	1.94	1.69	69.49
10/22/07	1.12	51683.33	2055.49	46283.58	85774.34	1.85	1.61	64.50
10/23/07	3.67	173533.81	1976.06	47327.40	81972.84	1.73	1.52	71.79
10/24/07	7.02	348275.72	1950.80	49635.49	84319.39	1.70	1.50	79.64
10/25/07	7.37	364419.74	1947.24	49468.74	84773.56	1.71	1.51	77.53
10/26/07	7.02	346957.62	1930.39	49447.64	86721.55	1.75	1.55	74.70
10/27/07	6.70	336141.40	1927.11	50170.36	84763.48	1.69	1.49	75.68
10/28/07	6.78	350047.71	1942.16	51604.08	82544.40	1.60	1.42	80.01
10/29/07	9.20	458348.98	1956.58	49820.54	83489.73	1.68	1.48	78.88
10/30/07	10.55	522110.30	1924.64	49489.13	82560.24	1.67	1.47	75.68
10/31/07	8.28	389889.25	1948.43	47069.12	87798.83	1.87	1.63	72.13
Ave.	N/A	N/A	2086.42	53239.40	92462.55	1.74	1.53	74.73
Dev.	N/A	N/A	241.03	10518.94	16539.63	0.26	0.22	5.00
SUM	234.10	12723749.50	66765.52	1543942.56	2681414.06	51.27	45.22	2391.35

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 20							
Site	Davis-Monthan AFB							
Analysis Period:	November 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
10/31/07	0.25	11816.67	1974.39	47266.67	82340.78	1.74	1.52	64.47
11/01/07	8.40	398356.84	1942.36	47423.43	82725.86	1.74	1.53	70.47
11/02/07	7.88	371673.00	1938.03	47146.68	81465.30	1.73	1.52	69.35
11/03/07	8.62	417231.73	1931.23	48515.32	77084.52	1.59	1.40	72.76
11/04/07	10.87	537181.95	1929.07	49433.92	76837.36	1.55	1.37	76.10
11/05/07	10.80	538675.40	1921.33	49877.35	78976.86	1.58	1.40	75.43
11/06/07	10.38	513073.83	1920.18	49413.21	79931.17	1.62	1.43	75.66
11/07/07	12.15	626214.16	2002.16	51540.26	81322.78	1.58	1.39	76.20
11/08/07	9.43	461038.79	1923.45	48873.37	81498.80	1.67	1.47	73.96
11/09/07	6.12	291928.05	1959.33	47726.66	85919.33	1.80	1.58	71.67
11/10/07	3.95	183585.00	1974.23	46477.21	88704.37	1.91	1.67	69.96
11/11/07	3.08	143416.67	1978.04	46513.51	90540.68	1.95	1.70	66.59
11/12/07	1.52	70716.67	1999.54	46626.37	92880.30	1.99	1.74	66.27
11/13/07	3.30	155138.33	1969.57	47011.62	95063.23	2.02	1.77	69.76
11/14/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	61.92
11/18/07	0.43	19792.01	2085.00	47500.82	93228.77	1.96	1.71	68.93
11/19/07	0.55	26373.35	1957.92	47951.55	89181.76	1.86	1.63	81.50
11/20/07	3.95	189170.49	1945.63	47891.26	86570.46	1.81	1.59	75.79
11/21/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	62.87

Note: F.O. stands for the unit was operable but the tenant was running the fans only.

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 20							
Site	Davis-Monthan AFB							
Analysis Period:	December 2007							
Mode of Operation:	Heating and cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
12/06/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	70.56
12/07/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	64.40
12/08/07	1.93	112995.83	58446.12	2897.43	86866.95	1.49	1.27	53.33
12/09/07	3.97	228627.45	57637.17	2816.88	70529.97	1.22	1.05	52.72
12/10/07	2.57	148202.69	57741.31	2803.02	70467.21	1.22	1.05	50.24
12/11/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	45.27
12/12/07	0.18	12565.81	68540.76	2886.86	180022.33	2.63	2.30	45.67
12/13/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	49.84
12/14/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	46.23
12/15/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	44.45
12/16/07	0.00	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	51.77
12/17/07	8.33	568284.28	68330.78	2652.75	59494.15	0.87	0.77	54.32
12/18/07	24.00	1620735.28	67530.64	2612.93	53504.78	0.79	0.70	53.68
12/19/07	24.00	1683391.81	70141.33	2683.92	51177.99	0.73	0.65	50.40
12/20/07	24.00	1612921.82	67205.08	2646.89	51576.23	0.77	0.68	50.68
12/21/07	24.00	1657874.44	69078.10	2692.34	50621.73	0.73	0.65	48.18
12/22/07	24.00	1567120.89	65296.70	2732.39	43021.94	0.66	0.58	41.34
12/23/07	24.00	1592157.04	66339.88	2723.84	43521.82	0.66	0.58	43.75
12/24/07	24.00	1621363.57	67556.82	2671.14	47703.65	0.71	0.62	50.44
12/25/07	23.98	1631472.27	68025.25	2729.12	67272.54	0.99	0.87	45.57
12/26/07	23.97	1583467.53	66069.58	2713.71	116118.76	1.76	1.54	42.95
12/27/07	24.00	1550000.27	64583.34	2735.79	44595.15	0.69	0.60	39.73
12/28/07	23.98	1549910.26	64624.47	2737.47	82382.70	1.27	1.11	39.83
12/29/07	24.00	1582776.49	65949.02	2723.91	44132.34	0.67	0.59	42.77
12/30/07	24.00	1629201.93	67883.41	2700.78	44114.96	0.65	0.57	47.02
12/31/07	22.68	1562799.46	68896.38	2695.09	45445.81	0.66	0.58	49.09

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 20							
Site	Davis-Monthan AFB							
Analysis Period:	January 2008							
Mode of Operation:	Heating/Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
01/01/08	23.93	1685249.35	70414.32	2692.88	73504.32	1.04	0.92	52.53
01/02/08	23.93	1720136.45	71872.00	2669.03	76589.90	1.07	0.95	56.04
01/03/08	23.93	1622473.98	67838.63	2604.50	70367.00	1.04	0.92	59.24
01/04/08	24.00	1547859.60	64494.15	2462.85	64126.02	0.99	0.88	61.36
01/05/08	24.00	1550210.64	64592.11	2484.50	64453.96	1.00	0.88	61.94
01/06/08	24.00	1734863.41	72285.98	2647.71	78467.06	1.09	0.96	60.04
01/07/08	23.90	1718296.22	71895.24	2677.90	76512.88	1.06	0.94	54.87
01/08/08	24.00	1628911.38	67871.31	2678.18	69665.31	1.03	0.90	52.76
01/09/08	24.00	1623489.41	67645.39	2674.73	68298.57	1.01	0.89	50.61
01/10/08	24.00	1634100.85	68134.85	2695.84	68581.75	1.01	0.89	49.53
01/11/08	24.00	1625967.83	67748.66	2668.30	68059.79	1.00	0.89	50.76
01/12/08	24.00	1605893.03	66912.21	2643.82	66724.55	1.00	0.88	51.03
01/13/08	24.00	1666632.31	69443.01	2707.21	70756.59	1.02	0.90	50.61
01/14/08	24.00	1654639.12	68943.30	2683.97	70408.94	1.02	0.90	52.82
01/15/08	24.00	1640239.74	68343.32	2672.13	69915.21	1.02	0.90	53.03
01/16/08	24.00	1649574.12	68732.26	2694.39	69039.94	1.00	0.89	48.97
01/17/08	23.88	1598338.06	66922.74	2716.19	65072.86	0.97	0.85	44.58
01/18/08	24.00	1587881.84	66161.74	2722.92	63837.29	0.96	0.85	43.48
01/19/08	23.90	1604926.48	67151.74	2711.22	66628.32	0.99	0.87	47.10
01/20/08	23.88	1644966.51	68875.08	2682.06	71246.89	1.03	0.91	52.42
01/21/08	23.92	1628922.27	68108.25	2678.92	69295.43	1.02	0.90	51.67
01/22/08	24.00	1644298.66	68512.44	2651.00	69380.24	1.01	0.89	53.19
01/23/08	24.00	1702182.44	70924.27	2665.92	73763.71	1.04	0.92	54.12
01/24/08	24.00	1691478.32	70478.26	2666.61	73068.35	1.04	0.92	54.07
01/25/08	24.00	1600819.68	66700.82	2614.04	66843.98	1.00	0.88	54.03
01/26/08	24.00	1596911.38	66537.97	2571.23	66573.46	1.00	0.88	57.07
01/27/08	24.00	1743792.37	72658.02	2651.76	78305.30	1.08	0.96	58.40
01/28/08	24.00	1725713.46	71904.73	2658.71	76183.35	1.06	0.94	57.63
01/29/08	24.00	1640238.33	68343.26	2695.50	69889.81	1.02	0.90	51.51
01/30/08	24.00	1597669.98	66569.58	2719.76	66253.71	1.00	0.87	47.77
01/31/08	20.90	1371846.33	65638.58	2719.87	63516.47	0.97	0.85	45.25
12/31/07	1.32	85874.34	65221.02	2712.95	61353.79	0.94	0.82	42.91
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

Unit:	GHP 20							
Site	Davis-Monthan AFB							
Analysis Period:	February 2008							
Mode of Operation:	Heating and Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
01/31/08	3.10	200603.90	64710.93	2719.98	60862.46	0.94	0.82	43.15
02/01/08	24.00	1625002.28	67755.48	2685.68	67566.35	1.00	0.88	50.15
02/02/08	23.98	1659441.15	69191.43	2674.17	71085.77	1.03	0.91	54.24
02/03/08	24.00	1683389.02	70141.21	2683.72	72767.21	1.04	0.92	55.90
02/04/08	23.90	1619035.80	67789.36	2691.69	67681.03	1.00	0.88	47.71
02/05/08	14.48	941794.65	65026.10	2716.16	61444.25	0.94	0.83	42.52
02/06/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	44.93
02/07/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	48.78
02/08/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	53.03
02/09/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	56.59
02/10/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	60.98
02/11/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	59.77
02/12/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	58.55
02/13/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	62.19
02/14/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	61.85
02/15/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	43.86
02/16/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	45.58
02/17/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	50.87
02/18/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	55.24
02/19/08	12.07	825446.28	68407.15	2490.32	68525.23	1.00	0.89	59.30
02/20/08	24.00	1713024.32	71425.61	2628.36	73657.42	1.03	0.92	57.81
02/21/08	24.00	1720764.63	71698.53	2657.69	73465.74	1.02	0.91	55.72
02/22/08	24.00	1723619.68	71817.49	2652.44	74323.28	1.03	0.92	56.92
02/23/08	24.00	1607150.07	67057.72	2548.16	65941.60	0.98	0.87	58.99
02/24/08	23.95	1477169.96	61677.24	2402.20	57610.08	0.93	0.82	63.96
02/25/08	24.00	1547325.71	64471.90	2467.49	61699.54	0.96	0.85	60.78
02/26/08	23.70	1455781.63	61425.39	2397.45	56076.90	0.91	0.81	61.50
02/27/08	16.65	1084436.53	65131.32	2510.02	63830.45	0.98	0.87	65.68
02/28/08	11.93	842091.49	70566.33	2610.09	71146.24	1.01	0.90	58.06

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Appendix F: GHP 21 Performance Data

Unit:	GHP 21
Site	Yuma MCAS
Analysis Period:	July 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
07/01/07	10.80	1088904.51	3435.92	100824.49	93353.66	0.93	0.83	102.57
07/02/07	3.23	278178.58	3524.03	86034.61	99104.25	1.15	1.01	84.31
07/03/07	5.15	348218.02	2389.37	67615.15	69675.45	1.03	0.92	99.05
07/04/07	20.47	1261306.33	2325.85	61627.35	65756.13	1.07	0.95	95.68
07/05/07	1.48	79683.01	1985.96	53718.88	60579.45	1.13	1.00	89.63
07/11/07	5.50	367635.26	2205.40	66842.77	65703.10	0.98	0.88	100.57
07/12/07	15.02	990639.35	2659.24	65969.32	65093.61	0.99	0.87	94.81
07/13/07	15.48	1376498.32	3374.20	88901.94	88968.51	1.00	0.89	91.09
07/14/07	21.37	1541053.94	2744.95	72124.21	77081.10	1.07	0.95	92.79
07/15/07	15.85	1069702.49	2726.97	67489.12	66049.31	0.98	0.86	96.04
07/16/07	13.47	1334826.55	3456.30	99120.78	79457.78	0.80	0.72	98.99
07/17/07	23.57	1908353.46	2977.64	80976.81	71653.90	0.88	0.79	97.86
07/18/07	22.32	1735543.07	2902.50	77768.92	70048.47	0.90	0.80	95.24
07/19/07	22.80	1790371.50	2979.62	78525.07	71906.38	0.92	0.81	93.18
07/20/07	22.58	1793897.02	3175.84	79434.55	76159.76	0.96	0.84	90.05
07/21/07	23.42	1672530.49	2793.90	71424.79	76065.83	1.06	0.94	89.56
07/22/07	20.13	1412099.58	2811.37	70137.40	70981.04	1.01	0.89	91.21
07/23/07	22.98	1804215.42	2925.43	78501.03	72084.18	0.92	0.81	94.67
07/24/07	13.55	915186.94	2730.62	67541.47	75114.45	1.11	0.98	89.21
07/25/07	15.60	1414995.47	3438.35	90704.84	89972.70	0.99	0.88	89.48
07/26/07	20.98	1792282.38	3323.68	85414.57	92390.90	1.08	0.95	90.73
07/27/07	22.63	1927620.77	3429.15	85167.34	97004.93	1.14	1.00	91.49
07/28/07	24.00	1995382.06	3369.18	83140.92	98234.17	1.18	1.04	95.00
07/29/07	22.95	1674968.12	2846.90	72983.36	87524.62	1.20	1.06	93.27
07/30/07	21.25	1678494.53	3008.54	78987.98	87380.70	1.11	0.98	95.60
07/31/07	23.60	1807161.93	3036.74	76574.66	97184.56	1.27	1.12	90.95

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 21							
Site	Yuma MCAS							
Analysis Period:	August 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
07/31/07	0.37	19135.01	1923.74	52186.39	70139.14	1.25	1.19	87.47
08/01/07	22.25	1567474.11	2731.47	70448.27	87874.24	1.15	1.13	89.48
08/02/07	16.27	1116008.45	2876.73	68607.08	86014.74	1.14	1.11	93.61
08/03/07	0.55	47411.96	3302.72	86203.56	83430.95	1.04	0.81	95.69
08/04/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	95.47
08/05/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	87.76
08/06/07	0.02	886.34	2559.36	53180.45	61568.28	1.24	1.02	87.89
08/07/07	9.07	705229.32	2950.50	77782.65	87575.60	1.07	1.02	89.36
08/08/07	16.83	1232164.34	2989.31	73197.88	93792.65	1.15	1.15	92.22
08/09/07	14.50	1252583.18	3336.20	86385.05	107558.98	1.03	1.11	91.72
08/10/07	23.33	1686960.91	2700.07	72298.32	92484.41	1.12	1.15	91.94
08/11/07	23.37	1776468.79	2860.35	76025.77	94141.52	1.08	1.12	95.04
08/12/07	4.12	217740.54	1930.15	52892.44	69431.80	1.24	1.17	88.19
08/14/07	10.72	882278.38	2832.68	82327.69	94445.88	1.02	1.03	99.71
08/15/07	20.82	1583426.02	2544.19	76065.30	91837.93	1.06	1.10	97.47
08/16/07	21.93	1752945.78	2945.46	79921.54	100150.00	1.05	1.14	97.28
08/17/07	20.45	1589957.91	2819.05	77748.55	95574.20	1.04	1.12	98.87
08/18/07	21.55	1609697.18	2856.03	74695.92	92071.94	1.06	1.11	98.58
08/19/07	11.52	875594.64	3130.86	76028.48	106026.33	1.12	1.23	92.71
08/20/07	6.30	490508.77	2966.41	77858.53	98140.09	1.06	1.14	93.08
08/21/07	3.63	190110.12	1946.27	52323.89	74451.25	1.24	1.26	87.67

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 21							
Site	Yuma MCAS							
Analysis Period:	September 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
09/27/07	6.27	345203.67	N/A	55085.69	0.32	0.00	0.00	91.46
09/28/07	12.38	840044.16	N/A	67836.68	0.50	0.00	0.00	81.71
09/29/07	6.87	309324.47	N/A	45047.25	0.37	0.00	0.00	76.75
09/30/07	9.50	460847.86	N/A	48510.30	0.37	0.00	0.00	80.70
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

Unit:	GHP 21							
Site	Yuma MCAS							
Analysis Period:	October 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
09/30/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	81.13
10/01/07	13.12	680716.77	2282.87	51963.11	83060.69	1.60	1.39	81.22
10/02/07	13.53	704223.81	1998.05	52100.41	77707.18	1.49	1.32	83.64
10/03/07	15.90	907550.70	2233.75	57078.66	86719.20	1.52	1.34	87.38
10/04/07	15.62	830902.15	1990.04	53206.11	77979.74	1.47	1.30	86.48
10/05/07	8.77	405869.06	1968.35	46296.85	72693.46	1.57	1.37	73.58
10/06/07	2.13	99223.05	2056.30	46510.81	66335.96	1.43	1.24	67.67
10/07/07	2.72	129618.78	2025.55	48006.96	61042.13	1.27	1.11	72.06
10/08/07	4.48	224236.73	1987.04	50015.63	60864.78	1.22	1.07	75.65
10/09/07	6.27	322543.75	2005.22	51607.00	67020.19	1.30	1.15	75.70
10/10/07	7.13	358513.86	1941.83	50376.65	64576.26	1.28	1.13	77.07
10/11/07	7.42	373178.48	1927.61	50429.52	64500.03	1.28	1.13	76.89
10/12/07	7.77	377580.36	1941.10	48825.05	65361.59	1.34	1.18	74.49
10/13/07	4.65	218338.23	1998.78	47123.36	68056.41	1.44	1.26	72.25
10/14/07	5.52	269412.91	1978.47	48984.16	69854.47	1.43	1.25	74.19
10/15/07	7.50	373542.93	1927.46	50028.07	69488.09	1.39	1.23	76.99
10/16/07	6.23	291767.65	1976.64	46807.64	70908.80	1.51	1.32	72.90
10/17/07	4.98	234839.10	1972.19	47283.04	72369.41	1.53	1.34	71.95
10/18/07	4.53	221331.85	1975.05	49003.36	67975.61	1.39	1.22	73.72
10/19/07	5.48	280173.01	1938.64	51251.16	64272.71	1.25	1.11	78.24
10/20/07	7.32	379925.86	1946.61	52163.73	66218.93	1.27	1.13	78.63
10/21/07	3.68	176373.65	2039.37	47884.25	61122.81	1.28	1.11	73.95
10/22/07	3.37	168333.71	1997.32	50000.11	58983.11	1.18	1.04	72.47
10/23/07	3.93	198951.12	1987.88	50580.79	57095.97	1.13	1.00	75.04
10/24/07	5.53	293049.16	1933.29	53120.69	58071.86	1.09	0.97	79.23
10/25/07	7.72	403683.81	1918.85	52426.47	63323.76	1.21	1.07	80.77
10/26/07	8.05	450693.58	2269.78	56102.93	72760.75	1.30	1.14	76.97
10/27/07	5.90	294454.36	1971.64	49907.52	63989.87	1.28	1.13	76.67
10/28/07	6.72	342039.04	1980.68	50923.93	63479.10	1.25	1.10	78.28
10/29/07	8.42	438485.03	1926.42	52200.60	62689.32	1.20	1.07	80.39
10/30/07	9.33	446263.14	1978.64	47813.91	71784.68	1.50	1.32	75.54
10/31/07	5.80	284977.94	1975.68	49134.13	69383.49	1.41	1.24	72.98

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 21							
Site	Yuma MCAS							
Analysis Period:	November 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
10/31/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	69.13
11/01/07	5.98	294760.03	1945.75	49263.51	72010.25	1.46	1.29	74.02
11/02/07	5.33	263677.02	1961.02	49439.44	66461.18	1.34	1.18	74.62
11/03/07	3.87	193279.35	2008.24	49986.04	66680.54	1.33	1.17	74.60
11/04/07	4.27	216527.01	1993.42	50748.52	64537.88	1.27	1.12	77.04
11/05/07	5.50	275029.28	1931.24	50005.32	67931.01	1.36	1.20	76.05
11/06/07	5.22	257459.71	1920.08	49511.48	69590.47	1.41	1.24	73.65
11/07/07	6.12	310022.23	1914.05	50823.32	67416.00	1.33	1.18	75.34
11/08/07	5.77	277236.96	1907.33	48215.12	72539.67	1.50	1.33	71.99
11/09/07	4.88	226400.00	1969.96	46520.55	77873.86	1.67	1.46	68.37
11/10/07	0.82	37116.67	2030.34	46395.83	73687.05	1.59	1.38	66.45
11/11/07	0.97	44333.33	1993.14	46666.67	68034.33	1.46	1.27	65.36
11/12/07	2.35	110622.13	1962.78	47073.25	72776.63	1.55	1.35	71.39
11/13/07	3.35	161593.11	1965.32	48477.93	72992.10	1.51	1.32	73.07
11/14/07	3.47	170033.68	1942.07	49048.18	69967.06	1.43	1.26	73.33
11/15/07	4.03	199065.04	1933.53	49354.97	70282.47	1.42	1.26	74.87
11/16/07	3.68	177736.37	1944.76	48473.55	70282.34	1.45	1.28	73.94
11/17/07	3.10	146986.80	1986.13	47415.10	74193.67	1.56	1.37	71.19
11/18/07	2.85	138507.87	1999.64	48599.25	71787.79	1.48	1.30	71.17
11/19/07	3.65	179041.34	1925.74	49052.42	69444.31	1.42	1.25	71.58
11/20/07	3.42	162122.90	1963.83	47450.60	72506.80	1.53	1.34	69.80
11/21/07	0.25	10733.33	2068.74	46000.00	84716.64	1.84	1.60	64.95
11/22/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	63.03
11/23/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	58.48
11/24/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	62.09
11/25/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	59.23
11/26/07	0.08	3066.67	2079.68	46000.00	46507.84	1.01	0.88	60.43
11/27/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	61.05
11/28/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	62.78
11/29/07	0.05	2166.67	3191.17	65000.00	51867.58	0.80	0.68	63.54
11/30/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	60.70

Note: F.O. stands for the unit was operable but the tenant was running the fans only.

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 21
Site	Yuma MCAS
Analysis Period:	December 2007
Mode of Operation:	Heating and cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
12/01/07	0.02	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/02/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	54.69
12/03/07	0.03	1533.33	46000.00	2167.37	99096.14	2.15	1.86	57.55
12/04/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	61.05
12/05/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	60.85
12/06/07	0.03	2166.67	65000.00	3692.09	58807.70	0.90	0.76	61.62
12/07/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	62.48
12/08/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	56.11
12/09/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	53.32
12/10/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	54.09
12/11/07	0.05	2300.00	46000.00	2134.06	89569.25	1.95	1.68	52.20
12/12/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	52.00
12/13/07	0.03	2166.67	65000.00	3932.12	68678.25	1.06	0.88	53.22
12/14/07	0.25	16250.00	65000.00	3966.05	72436.08	1.11	0.92	52.94
12/15/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	52.50
12/16/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	52.19
12/17/07	0.05	2616.67	52333.33	2778.52	64339.52	1.23	1.04	52.93
12/18/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	53.62
12/19/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	53.85
12/20/07	0.03	1850.00	55500.00	3068.35	102514.52	1.85	1.55	64.27
12/21/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	56.37
12/22/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	51.03
12/23/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	52.39
12/24/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	56.15
12/25/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	54.94
12/26/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	49.80
12/27/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	50.67
12/28/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	48.05
12/29/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	49.16
12/30/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	51.59
12/31/07	0.00	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	Cycled Off	54.65

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Appendix G: GHP 22 Performance Data

Unit:	GHP 22
Site	Ft. Huachuca AG
Analysis Period:	June 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
06/01/07	4.28	369296.49	3150.60	86217.08	103728.84	1.07	1.20	85.88
06/13/07	8.72	601406.75	2982.41	68995.04	95170.36	1.20	1.38	79.68
06/14/07	1.50	57645.16	2440.43	38430.11	85814.30	1.84	2.23	68.74
06/27/07	0.00	0.00	56.37	U.O.	U.O.	U.O.	U.O.	100.16
06/28/07	21.38	1381842.62	2799.33	64622.41	97822.34	1.32	1.51	82.14
06/29/07	24.00	1478963.24	2827.44	61623.47	79939.92	1.12	1.30	82.15
06/30/07	1.70	74885.97	2309.70	44050.57	68813.07	1.32	1.56	77.30

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 22							
Site:	Ft. Huachuca							
Analysis Period:	July 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
07/06/07	6.97	562109.91	3167.27	80685.63	124176.32	1.36	1.54	76.47
07/07/07	24.00	1652315.30	2967.04	68846.47	108818.83	1.38	1.58	78.26
07/08/07	24.00	1479075.73	2854.69	61628.16	87465.05	1.23	1.42	79.15
07/09/07	24.00	1458957.80	2756.60	60789.91	98643.98	1.41	1.62	79.11
07/10/07	24.00	1353812.24	2730.16	56408.84	82327.36	1.25	1.46	78.84
07/11/07	24.00	1058619.77	2470.25	44109.16	117457.46	2.24	2.66	75.04
07/12/07	24.00	1026066.65	2411.19	42752.78	81963.30	1.61	1.92	74.83
07/13/07	24.00	1341810.32	2919.21	55908.76	74587.81	1.13	1.33	77.19
07/14/07	24.00	1107900.30	2402.90	46162.51	69839.76	1.28	1.51	78.36
07/15/07	24.00	1347409.79	2832.27	56142.07	77050.77	1.17	1.37	78.73
07/16/07	24.00	1226823.81	2596.59	51117.66	73715.70	1.23	1.44	78.42
07/17/07	24.00	1424513.56	2998.50	59354.73	73207.02	1.05	1.23	81.17
07/18/07	24.00	1485126.20	2743.07	61880.26	86983.34	1.22	1.41	82.33
07/19/07	24.00	1405711.12	2870.96	58571.30	80362.83	1.18	1.37	78.53
07/20/07	24.00	1144487.18	2859.03	47686.97	68988.61	1.20	1.45	73.24
07/21/07	4.82	159741.96	2206.93	33164.42	33893.78	0.83	1.02	70.85
07/22/07	0.00	0.00	3045.70	U.O.	U.O.	U.O.		73.61
07/23/07	0.00	0.00	3062.57	U.O.	U.O.	U.O.		70.65

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 22
Site:	Ft. Huachuca AG
Analysis Period:	August 2007
Mode of Operation:	Cooling

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
08/01/07	0.00	0.00	3062.26	U.O.	U.O.	U.O.	U.O.	68.74
08/02/07	0.00	0.00	3057.84	U.O.	U.O.	U.O.	U.O.	71.02
08/03/07	13.58	933418.68	3036.05	68717.94	110903.45	1.40	1.61	73.11
08/04/07	24.00	926225.21	2309.37	38592.72	47814.51	1.03	1.24	71.54
08/05/07	7.00	243374.81	1841.45	34767.83	27025.79	0.66	0.78	68.55
08/06/07	0.00	0.00	3085.36	U.O.	U.O.	U.O.	U.O.	66.43
08/07/07	0.00	0.00	3067.47	U.O.	U.O.	U.O.	U.O.	69.72
08/08/07	10.98	868623.64	3097.39	79085.61	124634.48	1.39	1.58	73.80
08/09/07	23.62	1007939.06	2494.05	42679.14	66666.22	1.30	1.56	74.44
08/10/07	3.42	114074.95	2895.24	33387.79	35438.52	0.82	1.06	74.00
08/11/07	0.00	0.00	2906.94	U.O.	U.O.	U.O.	U.O.	76.40
08/12/07	0.00	0.00	2895.33	U.O.	U.O.	U.O.	U.O.	80.34
08/13/07	0.00	0.00	2895.72	U.O.	U.O.	U.O.	U.O.	80.60
08/14/07	0.00	0.00	2898.62	U.O.	U.O.	U.O.	U.O.	77.44
08/15/07	0.00	0.00	2892.42	U.O.	U.O.	U.O.	U.O.	77.98
08/16/07	0.00	0.00	2894.61	U.O.	U.O.	U.O.	U.O.	77.74
08/17/07	0.00	0.00	2891.48	U.O.	U.O.	U.O.	U.O.	78.82
08/18/07	0.00	0.00	2899.48	U.O.	U.O.	U.O.	U.O.	77.90
08/19/07	0.00	0.00	2902.30	U.O.	U.O.	U.O.	U.O.	77.49
08/20/07	0.00	0.00	2901.83	U.O.	U.O.	U.O.	U.O.	77.49
08/21/07	0.00	0.00	2889.24	U.O.	U.O.	U.O.	U.O.	81.61
08/22/07	0.00	0.00	2886.65	U.O.	U.O.	U.O.	U.O.	80.50
08/23/07	0.00	0.00	2886.31	U.O.	U.O.	U.O.	U.O.	78.73
08/24/07	13.13	1065673.29	2971.22	81142.64	111678.67	1.22	1.38	76.25
08/25/07	1.05	86457.68	2913.96	82340.65	85813.69	0.93	1.04	72.60
08/26/07	0.00	0.00	2913.94	U.O.	U.O.	U.O.	U.O.	72.38
08/27/07	0.00	0.00	2906.38	U.O.	U.O.	U.O.	U.O.	75.46
08/28/07	8.67	705363.04	2938.70	81388.04	114736.57	1.26	U.O.	77.32
08/29/07	0.00	0.00	2896.57	U.O.	U.O.	U.O.	U.O.	79.35
08/30/07	13.08	1050822.83	3035.42	80317.67	121626.91	1.34	U.O.	75.34
08/31/07	0.00	0.00	3033.00	U.O.	U.O.	U.O.	U.O.	77.25

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 22							
Site	Ft. Huachuca							
Analysis Period:	September 2007							
Mode of operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
08/31/07	0.00	0.00	3048.18	U.O.	U.O.	U.O.	U.O.	70.48
09/01/07	0.00	0.00	3039.54	U.O.	U.O.	U.O.	U.O.	74.98
09/02/07	0.00	0.00	3036.15	U.O.	U.O.	U.O.	U.O.	76.41
09/03/07	0.00	0.00	3032.05	U.O.	U.O.	U.O.	U.O.	78.46
09/04/07	0.00	0.00	3054.72	U.O.	U.O.	U.O.	U.O.	70.43
09/06/07	6.17	420054.53	2472.33	68116.95	114799.24	1.69	1.49	72.43
09/07/07	8.68	355662.69	1995.26	40959.23	62491.34	1.53	1.30	72.27
09/08/07	14.07	663269.28	2375.94	47151.84	63685.73	1.35	1.15	75.34
09/09/07	12.63	541357.83	2514.91	42851.54	52770.27	1.23	1.02	73.26
09/10/07	10.07	463695.54	2087.01	46062.47	61824.64	1.34	1.16	72.63
09/11/07	16.62	732138.68	2605.66	44060.50	58500.86	1.33	1.10	75.38
09/12/07	16.83	765561.90	2656.43	45478.92	58648.21	1.29	1.07	76.48
09/13/07	14.67	726923.69	2925.38	49562.98	75099.00	1.52	1.25	78.28
09/14/07	0.02	581.87	3526.34	34912.35	55744.18	1.60	1.18	77.68
09/15/07	13.35	621066.16	3707.68	46521.81	67571.34	1.45	1.13	77.06
09/16/07	11.93	479489.03	2305.41	40180.64	51996.98	1.29	1.08	69.38
09/17/07	6.27	274586.77	1815.37	43817.04	60509.40	1.38	1.21	69.95
09/18/07	3.53	132864.91	1800.03	37603.28	56178.22	1.49	1.28	67.37
09/19/07	7.95	355904.55	2059.76	44767.87	60204.66	1.34	1.16	69.91
09/20/07	0.00	0.00	2500.80	U.O.	U.O.	U.O.	U.O.	70.09
09/21/07	0.00	0.00	3155.05	U.O.	U.O.	U.O.	U.O.	72.28
09/22/07	0.00	0.00	3665.56	U.O.	U.O.	U.O.	U.O.	72.96
09/23/07	0.00	0.00	3670.87	U.O.	U.O.	U.O.	U.O.	70.34
09/24/07	0.00	0.00	3684.50	U.O.	U.O.	U.O.	U.O.	67.90
09/25/07	0.00	0.00	3056.73	U.O.	U.O.	U.O.	U.O.	69.86
09/26/07	0.00	0.00	3686.80	U.O.	U.O.	U.O.	U.O.	71.12
09/27/07	0.00	0.00	3679.02	U.O.	U.O.	U.O.	U.O.	72.99
09/28/07	0.00	0.00	3675.73	U.O.	U.O.	U.O.	U.O.	72.94
09/29/07	0.00	0.00	3672.58	U.O.	U.O.	U.O.	U.O.	72.23
09/30/07	0.00	0.00	3684.60	U.O.	U.O.	U.O.	U.O.	70.83

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 22							
Site	Ft. Huachuca							
Analysis Period:	October 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
09/30/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	65.35
10/01/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	67.09
10/02/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	67.42
10/03/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	71.20
10/04/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	72.04
10/05/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	69.98
10/06/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	64.47
10/07/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	56.92
10/08/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	68.30
10/09/07	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	74.54
10/10/07	8.37	386081.81	3740.10	46703.45	56063.52	1.20	0.94	70.52
10/11/07	16.45	782247.59	3676.25	47553.05	57348.59	1.21	0.95	70.94
10/12/07	13.50	631337.85	3685.64	46765.77	54326.35	1.16	0.92	69.26
10/13/07	13.38	615633.33	3709.19	46000.00	49801.91	1.08	0.85	64.91
10/14/07	13.60	625916.67	2660.01	46023.28	44221.77	0.96	0.80	57.67
10/15/07	6.17	283666.67	1965.22	46000.00	54137.72	1.18	1.03	60.63
10/16/07	5.73	263733.33	1812.75	46000.00	51955.37	1.13	1.00	61.83
10/17/07	5.77	265583.33	1823.42	46054.91	49910.25	1.08	0.95	61.75
10/18/07	5.20	239200.00	1735.91	46000.00	51823.07	1.13	1.00	59.04
10/19/07	5.43	252223.59	1818.55	46421.52	57232.65	1.23	1.09	64.16
10/20/07	8.03	384404.99	2300.33	47851.24	57215.04	1.20	1.03	71.76
10/21/07	14.13	650133.33	3022.68	46000.00	46848.95	1.02	0.83	63.92
10/22/07	3.68	169750.00	1096.12	46085.97	41186.25	0.89	0.83	52.57
10/23/07	3.17	145983.33	1008.40	46100.00	44036.08	0.96	0.89	61.64
10/24/07	5.73	264050.00	1866.36	46055.23	52758.43	1.15	1.01	67.02
10/25/07	6.68	306666.67	2094.21	46000.00	53554.42	1.16	1.01	66.30
10/26/07	7.32	336624.06	2270.30	46007.84	54622.03	1.19	1.02	65.90
10/27/07	6.88	320570.96	2146.46	46572.05	55911.25	1.20	1.04	66.51
10/28/07	13.85	639571.13	2771.02	46178.42	48567.66	1.05	0.87	70.39
10/29/07	2.60	119916.67	2320.95	46121.79	41992.69	0.91	0.78	61.96

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 22							
Site	Ft. Huachuca							
Analysis Period:	November 2007							
Mode of Operation:	Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
10/31/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	59.32
11/01/07	4.30	197800.00	3267.26	46000.00	52626.55	1.14	0.92	62.91
11/02/07	4.90	225400.00	3336.16	46000.00	52840.52	1.15	0.92	62.25
11/03/07	4.55	209300.00	3285.26	46000.00	52283.80	1.14	0.91	64.24
11/04/07	4.42	203308.93	3070.00	46032.21	50359.67	1.09	0.89	65.18
11/05/07	5.08	234098.14	3163.08	46052.09	52948.83	1.15	0.93	66.01
11/06/07	4.68	215715.65	3076.63	46060.28	52482.85	1.14	0.93	66.37
11/07/07	4.87	224183.33	2361.23	46065.07	47968.01	1.04	0.89	65.52
11/08/07	5.58	256833.33	3349.58	46000.00	53607.29	1.17	0.93	65.36
11/09/07	4.92	226483.33	2362.88	46064.41	46139.00	1.00	0.85	63.84
11/10/07	2.72	124966.67	2370.46	46000.00	44920.21	0.98	0.83	62.15
11/11/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	59.44
11/12/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	55.45
11/13/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	59.36
11/14/07	2.18	100433.33	2371.12	46000.00	46625.00	1.01	0.86	62.37
11/15/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	59.59
11/16/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	57.80
11/17/07	2.82	129566.67	2380.04	46000.00	46393.41	1.01	0.86	60.71
11/18/07	2.22	101966.67	2374.30	46000.00	45327.78	0.99	0.84	60.06
11/19/07	3.33	153333.33	2369.47	46000.00	46373.81	1.01	0.86	62.80
11/20/07	3.63	167450.00	2369.08	46087.16	45426.83	0.99	0.84	63.62
11/21/07	3.70	170516.67	2370.80	46085.59	45338.38	0.98	0.84	63.30
11/22/07	2.82	129883.33	2379.35	46112.43	44591.03	0.97	0.82	60.21
11/23/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	52.15
11/24/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	39.21
11/25/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	41.59
11/26/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	47.29
11/27/07	0.00	0.00	F.O.	F.O.	F.O.	F.O.	F.O.	44.83

Note: F.O. stands for the unit was operable but the tenant was running the fans only.

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 22
Site	Ft. Huachuca
Analysis Period:	December 2007
Mode of Operation:	Heating

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
11/30/07	2.95	176156.69	59714.13	3720.14	46058.73	0.77	0.64	56.65
12/01/07	24.00	1367145.22	56964.38	3745.06	45663.04	0.80	0.65	50.36
12/02/07	24.00	1313991.13	54749.63	3716.74	44164.77	0.81	0.65	47.02
12/03/07	24.00	1359459.34	56644.14	3837.88	27908.24	0.49	0.40	49.51
12/04/07	22.80	1299385.54	56990.59	3560.40	33504.92	0.59	0.48	58.03
12/05/07	20.15	1103679.79	54773.19	3271.33	45502.76	0.83	0.69	61.77
12/06/07	22.20	1248677.60	56246.74	3407.46	55788.23	0.99	0.82	58.26
12/07/07	23.55	1312460.24	55730.80	3449.57	55261.70	0.99	0.82	55.00
12/08/07	24.00	1321149.21	55047.88	3793.87	41149.38	0.75	0.61	45.80
12/09/07	24.00	1228029.48	51167.90	3835.04	26310.46	0.51	0.41	36.78
12/10/07	24.00	430376.64	39294.59	3847.55	20905.54	0.53	0.40	9.16
12/11/07	24.00	804513.52	33521.40	3881.02	20215.13	0.60	0.43	-4.26
12/12/07	23.97	772695.61	32240.43	3886.78	19930.47	0.62	0.44	-7.24
12/13/07	24.00	701763.60	43370.80	3875.70	38113.63	0.88	0.67	19.48
12/14/07	24.00	1228069.41	51169.56	3871.57	46078.14	0.90	0.72	39.35
12/15/07	24.00	1192775.64	49698.99	3905.57	41496.37	0.83	0.66	35.23
12/16/07	24.00	1242794.48	51783.10	3881.78	42114.40	0.81	0.65	41.08
12/17/07	24.00	1430371.01	59640.21	3839.29	52071.48	0.87	0.72	47.08
12/18/07	24.00	1501032.98	62586.50	3875.78	55123.25	0.88	0.73	47.60
12/19/07	24.00	1545429.67	64437.65	3861.47	58504.45	0.91	0.75	48.43
12/20/07	24.00	1513226.40	63051.10	3827.12	57364.16	0.91	0.75	47.86
12/21/07	24.00	1489303.97	62054.33	3825.17	57498.39	0.93	0.77	44.19
12/22/07	24.00	1388899.11	57870.80	3901.03	49216.42	0.85	0.69	33.25
12/23/07	24.00	1438289.62	59928.73	3879.01	49927.81	0.83	0.68	40.36
12/24/07	24.00	1544717.46	64363.23	3840.01	56066.23	0.87	0.72	47.74
12/25/07	24.00	1461332.57	60931.17	3850.98	52725.74	0.87	0.71	43.40
12/26/07	24.00	1454591.29	60650.09	3870.44	64271.99	1.06	0.87	37.19
12/27/07	24.00	1362034.53	57188.29	3885.57	65058.90	1.14	0.92	32.94
12/28/07	24.00	1396067.10	58412.85	3891.25	69720.93	1.19	0.97	31.36
12/29/07	24.00	1422889.39	59369.52	3873.79	68996.93	1.16	0.95	37.84
12/30/07	24.00	1521226.58	63827.69	3823.18	77490.04	1.21	1.01	44.45
12/31/07	22.23	1403361.55	63261.98	3819.61	73934.63	1.17	0.97	46.26

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 22							
Site:	Ft. Huachuca							
Analysis Period:	January 2008							
Mode of Operation:	Heating/Cooling							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
01/01/08	24.00	1501694.54	62832.41	3861.12	84000.77	1.34	1.11	43.81
01/03/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	48.28
01/04/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	54.40
01/05/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	56.67
01/06/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	50.81
01/07/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	45.94
01/08/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	44.42
01/09/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	45.58
01/10/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	45.85
01/11/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	48.86
01/12/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	46.22
01/13/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	43.28
01/14/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	43.00
01/15/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	44.73
01/16/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	44.60
01/17/08	12.15	759513.21	62597.24	3619.18	88774.43	1.42	1.18	37.10
01/18/08	24.00	1404058.04	58870.36	3617.09	70487.36	1.20	0.99	37.05
01/19/08	24.00	1449068.76	60715.17	3608.42	80000.72	1.32	1.10	37.74
01/20/08	23.98	1505768.42	63002.86	3566.99	83039.17	1.32	1.10	44.47
01/21/08	24.00	1510470.46	63509.62	3559.33	82611.08	1.30	1.09	45.64
01/22/08	24.00	1549290.43	64598.63	3540.80	89933.38	1.39	1.17	47.97
01/23/08	24.00	1526238.13	64217.59	3532.77	82441.86	1.28	1.08	48.89
01/24/08	24.00	1505962.33	63143.07	3542.14	89083.38	1.41	1.18	45.57
01/25/08	24.00	1462485.04	61277.31	3570.90	76204.57	1.24	1.04	44.21
01/26/08	14.25	887542.65	62723.86	3578.31	83012.22	1.32	1.11	48.61
01/27/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	52.97
01/28/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	48.93
01/29/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	39.99
12/31/07	1.77	106343.24	60194.29	3865.68	73248.97	1.22	1.00	39.98

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 22
Site	Ft. Huachuca
Analysis Period:	February 2008
Mode of Operation:	Heating

Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
02/08/08	5.42	382253.91	70787.76	3560.16	118926.51	1.68	1.43	55.74
02/09/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	53.11
02/10/08	0.00	0.00	U.O.	U.O.	U.O.	U.O.	U.O.	56.90
02/11/08	9.78	617691.45	63244.86	3575.63	107693.16	1.70	1.43	56.75
02/12/08	23.88	1342481.24	56288.52	3506.77	84448.18	1.50	1.24	52.09
02/13/08	14.77	845066.26	57422.40	3582.29	84792.75	1.48	1.22	55.09
02/14/08	11.93	691279.14	57928.42	3448.46	93984.10	1.62	1.35	53.79
02/15/08	24.00	1243616.84	51889.44	3619.00	72509.82	1.40	1.13	39.42
02/16/08	24.00	1234131.36	51709.41	3653.44	69913.63	1.35	1.09	39.02
02/17/08	23.90	1279992.48	53705.98	3537.25	79885.75	1.49	1.21	45.01
02/18/08	22.80	1239884.01	54580.37	3477.37	83405.81	1.53	1.26	49.33
02/19/08	21.15	1175013.31	55687.83	3378.02	86371.32	1.55	1.28	54.13
02/20/08	16.70	951718.32	56989.12	3581.60	95653.79	1.68	1.38	52.80
02/21/08	17.10	945940.28	55318.14	3605.17	96551.14	1.75	1.43	47.83
02/22/08	17.47	1030513.72	59055.23	3595.78	96084.34	1.63	1.35	50.67
02/23/08	13.07	752639.59	57599.97	3598.74	100771.92	1.75	1.44	54.74
02/24/08	9.98	576150.36	57711.22	3618.46	100081.93	1.73	1.43	60.93
02/25/08	2.30	141064.59	61332.43	3603.61	110657.80	1.80	1.50	62.30

Note: U.O. stands for an unscheduled outage

Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.

Unit:	GHP 22							
Site	Ft. Huachuca							
Analysis Period:	March 2008							
Mode of Operation:	Heating							
Date	Hour Counter	Fuel Usage Counter (Btu)	Electrical Power Input (W)	Fuel Usage (Btu/hr)	Airside Total Capacity (Btu/hr)	Airside COP (Unit)	Airside COP (System)	Outdoor Air Temp (°F)
02/29/08	0.73	44592.56	60808.03	3653.79	98809.99	1.62	1.35	58.15
03/01/08	6.05	352445.11	58255.39	3635.79	97870.96	1.68	1.38	60.70
03/02/08	9.77	562226.95	57565.90	3607.98	99656.87	1.73	1.43	54.84
03/03/08	19.95	1114612.37	56010.67	3621.98	89963.12	1.61	1.32	41.61
03/04/08	14.63	866067.38	59252.04	3601.01	97378.42	1.64	1.36	50.48
03/05/08	11.03	632377.23	57315.16	3593.91	100157.91	1.75	1.44	54.44
03/06/08	16.12	895367.96	55612.92	3624.00	92672.43	1.67	1.36	44.96
03/07/08	15.93	911763.67	57223.66	3625.73	93124.65	1.63	1.34	47.82
03/08/08	13.28	751792.73	56667.79	3602.47	94481.26	1.67	1.37	53.65
03/09/08	11.32	643716.89	56882.20	3604.81	96751.35	1.70	1.40	52.92
03/10/08	10.50	588384.07	56036.58	3632.85	94515.97	1.69	1.38	54.68
03/11/08	8.47	476581.74	56289.18	3629.62	95012.85	1.69	1.38	58.06
03/12/08	6.48	377661.09	58251.07	3615.49	100303.55	1.72	1.42	60.53
03/13/08	4.98	307215.31	61648.56	3600.58	107030.27	1.74	1.45	65.08
03/14/08	4.08	251280.68	61538.13	3607.54	106202.98	1.73	1.44	64.73
03/15/08	5.68	341578.56	60101.80	3609.55	103045.49	1.71	1.42	61.51
03/16/08	14.25	762812.94	53593.41	3616.25	87124.15	1.63	1.32	44.94
03/17/08	21.30	1191618.00	56032.19	3623.85	84513.18	1.51	1.24	36.56
03/18/08	15.67	939449.54	60156.85	3610.37	96162.83	1.60	1.33	47.25
03/19/08	11.22	627893.58	56061.93	3620.57	91848.91	1.64	1.34	55.17
03/20/08	7.18	407861.67	56778.89	3616.69	97401.48	1.72	1.41	60.65
03/21/08	4.98	289889.42	58171.79	3621.70	98480.80	1.69	1.40	62.06
03/22/08	4.73	274935.52	58084.97	3630.62	97855.27	1.68	1.39	61.06
03/23/08	5.90	336323.79	57004.03	3632.66	95245.10	1.67	1.37	59.71
03/24/08	1.98	117897.48	59444.11	3624.96	100260.68	1.69	1.40	54.55
02/29/08	0.73	44592.56	60808.03	3653.79	98809.99	1.62	1.35	58.15
03/01/08	6.05	352445.11	58255.39	3635.79	97870.96	1.68	1.38	60.70
Note: The above table used previous experimental fuel consumption values from Oak Ridge National Labs.								

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14. ABSTRACT

Results of field testing natural gas engine-driven heat pumps (GHP) at six southwestern U.S. Department of Defense (DoD) installations show that the technology can provide both energy savings and resource conservation. A summary is provided of three main objectives: (1) verifying technical feasibility of GHP technology for space heating and cooling applications, (2) field operation experience from the beta version of GHP systems for final product development, and (3) analyzing energy and economic performance of GHP systems during a 1-year period. During testing from April 2007 to March 2008, the units produced an average unit coefficient of performance (COP) of 1.38 in the heating season and 1.25 in the cooling season. These efficiencies translate to annual energy cost savings in heating and cooling at each site that ranged from $680–$2,134, as compared to using high-efficiency electric heat pumps (EHP). In addition, an estimated 261,473 gallons of fresh water was saved at power plants, due to the reduced consumption of electricity. Lessons learned from this project are implemented in further development of GHP technology. Field demonstration of the follow-up model is in progress at five DoD installations for FY08,to be the topic of a future technical report.

15. SUBJECT TERMS

utilities	heat distribution systems	cooling systems
gas engine-driven heat pump (GHP)	energy efficient, natural gas	energy conservation

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